

MOTOR COORDINATION AMONG GREEK CHILDREN: FROM ASSESSMENT TO INTERVENTION

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ABSTRACT

Background: Developmental Coordination Disorder (DCD) describes children with a difficulty to acquire age-specific motor skills. Although there is a significant body of literature addressing developmental and cognitive issues in children with DCD, few studies have actually examined the associations between DCD, physical activity and physical fitness. Therefore, the aim of the present research work was to assess these associations in a series of four successive studies which were set: a) (*study 1*) to estimate DCD prevalence rates in Greek children and investigate whether these children exhibit different obesity and cardiorespiratory fitness levels than an overseas sample, b) (*study 2*) to provide evidence on the association between DCD and physical fitness levels, c) (*study 3*) examine whether a motor skills and exercise training intervention programme affects motor proficiency in a cohort of elementary school children with and without DCD, and d) (*study 4*) to test the hypothesis that DCD is associated with CVD risk, identify modes of physical activity that mediate such an association and to evaluate the CSAPPA scale as a potential tool for identifying Greek children for DCD. **Methods:** The total of 574 Greek (Age: 11.46 ± 1.54 years; BMI: 19.96 ± 3.53) children were assessed for anthropometry, physical fitness (flexibility, hand strength, leg explosive power, speed and cardiorespiratory fitness), motor competence (i.e., short form of the Bruininks-Oseretsky Test of Motor Proficiency- BOTMP-sf) and subjected to two self assessments for: i) perception of adequacy for physical activity (CSAPPA scale), and ii) children's participation in physical activity (Participation Questionnaire - PQ). **Results:** *Study 1:* Greek children demonstrated significantly higher DCD prevalence rates ($p < 0.05$), higher body fat ($p < 0.05$) and were inferior in both cardiorespiratory fitness ($p < 0.05$) and motor competence ($p < 0.05$) compared to an overseas sample. *Study 2:* Greek children with DCD demonstrated significantly higher BMI values ($p < 0.01$) and lower leg explosive power ($p < 0.01$), speed ($p < 0.01$) and hand strength ($p < 0.01$) than those without DCD. *Study 3:* Results showed a significant main effect of time [$F_{(14, 115)} = 3.79$, $p < 0.001$; $\eta^2 = 0.32$] for motor competence ($p < 0.001$) between children with and without DCD. Significant main effects of

group (i.e intervention and control groups) [$F_{(42, 351)} = 4.01, p < 0.001; \eta^2 = 0.33$] were observed for BMI ($p < 0.01$), motor competence ($p < 0.01$), cardiorespiratory fitness ($p < 0.01$), hand strength ($p < 0.05$), leg explosive power ($p < 0.05$), speed ($p < 0.01$), and free time play activities ($p < 0.05$). *Study 4*: Chi-square comparisons and ANOVA, revealed significantly increased body mass ($p < 0.05$), BMI ($p < 0.05$) and inactivity ($p < 0.05$), as well as significantly decreased cardiorespiratory fitness ($p < 0.05$), motor competence ($p < 0.05$), CSAPPA indices, and participation in free play ($p < 0.05$) in children with DCD. Furthermore, BMI and cardiorespiratory fitness were significantly associated with motor competence ($p < 0.05$) with inactivity as the mediating factor ($p < 0.05$). ROC curve analyses for CSAPPA indicated an optimal cut-off at 62 points. **Conclusions:** 1) the relatively high DCD and obesity prevalence rates together with the low cardiorespiratory fitness suggest greater health risk for Greek children with the studied condition, 2) children with DCD tend to perform worse in selected physical fitness parameters compared to their normal peers, 3) motor skills and exercise training interventions for children with DCD may improve health and skills related fitness, and 4) inactivity mediates the relationship between DCD and CVD risk in children with DCD. Finally, the CSAPPA scale may serve as a practical and a cost-effective proxy assessment for identifying Greek children with DCD, however as this is not a standardised test for use with children, its use should be treated with caution until further validation work.

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LIST OF ABBREVIATIONS

ANCOVAs	Analysis of Covariates
40m ST	40m Speed Test
APA	American Psychiatric Association
ANOVA	Analysis of Variance
ADHD	Attention Deficit Hyperactivity Disorder
BIA	Bioelectrical Impedance Analysis
BMI	Body Mass Index
BOTMP	Bruininks-Oseretsky Test of Motor Proficiency
BOTMP- <i>sf</i>	Bruininks-Oseretsky Test of Motor Proficiency- <i>short form</i>
BOTMP- <i>lf</i>	Bruininks-Oseretsky Test of Motor Proficiency- <i>long form</i>
CF	Cardiorespiratory Fitness
CVD	Cardiovascular Disease
CNS	Central Nervous System
CSAPPA	Children's Self Perception of Adequacy in and Predilection for Physical Activity
CL _{OB}	Clinical Obesity
CI	Confidence Interval
DAMP	Deficits in Attention Motor Control and Perception
DCD	Developmental Coordination Disorder
DSM-IV	Diagnostic and Statistical Manual of Mental Health Disorders-IV
DSM-IV- <i>TR</i>	Diagnostic and Statistical Manual of Mental Health Disorders-IV- <i>Text Revision</i>
DEXA	Dual Energy X-Ray Absorptiometry
FVC	Forced Vital Capacity
HS	Hand Strength
IQ	Intelligence Quotient
ICD-10	International Classification of Diseases
IOTF	International Obesity Task Force
L _{CF}	Low Cardiorespiratory Fitness
MAS	Maximal Attained Speed

$\dot{V}O_{2max}$

Maximal Oxygen Uptake

MBD

Minimal Brain Function

MPD

Motor Perception Dysfunction Syndrome

M-ABC

Movement Assessment Battery for Children

MANOVA

Multivariate Analysis of Variance

DCD⁻

Negative Diagnosis for Developmental Coordination Disorder

PQ

Participation Questionnaire

PE

Physical Education

DCD⁺

Positive Diagnosis for Developmental Coordination Disorder

ROC

Receiver Operating Characteristics

SR

Sit and Reach

TOMI

Test of Motor Impairment

VJ

Vertical Jump

WHO

World Health Organization

CHAPTER 1: INTRODUCTION

Developmental Coordination Disorder (DCD) is the condition which describes children who demonstrate difficulties in the execution of age related motor skills in the absence of any known pathological or pervasive disorders (American Psychiatric Association, 1994). While proper acquisition of simple and complex motor skills is a fundamental element of the child's development (Mon-Williams et al., 1996), DCD seems to affect a substantial proportion of school-age population. Data suggest that children with DCD may stay unnoticed by the school system for many years (Willoughby and Polatajko, 1995). The underlying mechanisms that initiate DCD still remain unclear. Several scenarios indicate a minimal Central Nervous System (CNS) dysfunction as a cause for DCD (Hadders-Algra, 2000, O' Brien et al., 2008).

Although DCD has been thoroughly studied by different disciplines (psychological, motoric, clinical, health related), the available data lead to complex and controversial outcomes regarding identification, management and treatment of the condition in paediatric populations ranging from birth to adolescence. Nevertheless, substantial evidence exists to at least justify the use of different screening tools and intervention treatments worldwide (Hillier, 2007, Sugden and Chambers, 2003).

Only recently researchers have focused on the examination of physical fitness of children with DCD and the possible risks that these children may encounter (Cairney et al., 2005, Faught et al., 2005, Haga, 2008, Hands, 2008, Hands and Larkin, 2006). DCD children, who are usually heterogeneous in terms of severity of signs and symptoms present at diagnosis level, may experience compromised fitness levels (Faught et al., 2005).

Everyday activities of children with DCD require mastering of different motor skills (Missiuna et al., 2006). As physical fitness is partly defined by movement and motor skills, physical fitness is usually more than motor competence (Haga, 2008). Movement tasks and motor competence usually require – *inter alia* – speed, aerobic power, flexibility and muscular strength. Therefore, motor competence and fitness are profoundly interrelated (Schott

et al., 2007) and this relation leads to accurate execution of simple or more complex tasks (Haga, 2008).

Improved fitness is associated with short and long term health benefits (Sallis et al., 2000). The assessment of physical fitness levels in children with DCD, is of great importance, primarily due to the fact that increased fitness levels have been linked to the prevention of cardiovascular, musculoskeletal and psychological diseases and to the deterioration of health risks associated with morbidity and mortality in adulthood (Boreham et al., 2004, Warburton et al., 2006). Recent data suggest that children with DCD are at a great risk of developing consequent impairments which are related to their limited participation in physical activity (Poulsen et al., 2008). Since secondary consequences of having DCD are now more evident, professionals all over the world have re-targeted their focus in preventing these secondary harms, rather than try to change primary impairments (Missiuna et al., 2006). However, the extent to which children with DCD have access to formal diagnosis or screening in order to design effective intervention treatments for the control of health risks is related to many factors such as the screening setting (i.e school-based, clinical, occupational).

In the following pages, the author discusses issues regarding the prevalence, screening and management of children with DCD as well as the relation between DCD, physical activity and selected physical fitness components in Greek children. Furthermore, detailed information is given regarding the use of an exercise intervention training programme for the improvement of motor competence and physical fitness in children with DCD. Information is also provided in regard to the modes of physical activity that mediate the relation between DCD and cardiovascular disease risk factors for Greek children as well as on the effectiveness of a questionnaire, previously administered in children with DCD from other countries, for the screening of Greek children with DCD. This information appears in the relevant chapters that follow.

CHAPTER 2: REVIEW OF LITERATURE

2.1. Introduction

Early identification, prevention and intervention strategies for children at risk for developmental disorders is the primary focus for many research disciplines and has been the concern of researchers for many years (Hillier, 2007). Screened with a developmental disorder, quite often, places the affected individual in a difficult position in terms of everyday performance and proficiency over a variety of activities such as sports, emotional stress, educational attainment, social interactions and skills acquisition (Hay and Missiuna, 1998).

Indeed, children with poor motor coordination may find certain motor tasks difficult or even impossible and they might end up having negative feelings about themselves (Cummins et al., 2005, Green et al., 2006). At the same time these children are most likely to be stigmatized in the various settings they perform their everyday activities (Piek et al., 2000).

Critical aspects on a child's development are related to learning and practicing specific skills. If a child does not engage in adequate amounts of physical activity, and if professionals such as teachers or members of his/her family do not identify that a child is not being as active as expected, then this might be contributing to exacerbating a DCD issue. Children with various levels of motor incoordination may experience lack of fitness, depression, social isolation and decreased participation in physical activities (Faught et al., 2005, Poulsen and Ziviani, 2004, Rasmussen and Gillberg, 2000).

Contrary to the belief that some children with poor motor coordination may catch-up with the performance of their peers during adolescence (Cantell et al., 2003), overwhelming evidence suggest that these children tend not to simply grow out of it (Fox and Lent, 1996, Rasmussen and Gillberg, 2000). Indeed, growing body of evidence suggests that without proper intervention which includes a mixture of elements from the neuromotor, psychological, social and health disciplines, it is likely that the affected children will not overcome their difficulties (Hillier, 2007).

In the following pages the author will provide previous and current data on aspects associated with the present Thesis. Particularly, information will be provided on aspects of motor development of children, motor control theories and skill learning and acquisition as well as movement coordination. Information will also be given about the definition of DCD and how this was evolved through the ages, associated past and contemporary prevalence opinions and co-occurring disorders as well as on cognitive, perceptual and functional characteristics of children with DCD. Data will also be presented regarding the functional assessment of children with DCD. In detail this review will elaborate on the relation between physical fitness and DCD and the importance of exercise interventions for the functional performance of children with DCD. In particular, the following will be discussed:

- Motor development
- Models of motor development
- Theories of motor development
- Motor development and the role of brain function
- Motor control and skill learning
- Motor skills acquisition
- Planning and execution of movement
- Coordination
- Developmental coordination disorder
- Co-occurrence of DCD with other disorders
- Characteristics of children with DCD
- Assessment of movement skills
- Screening for DCD
- Comparisons of DCD screening instruments
- Physical fitness and DCD
- Physical fitness intervention programmes and DCD
- Physical activity of children with DCD
- Physical fitness, physical activity and obesity of Greek children

2.2. Motor Development

Development is a continuous process of change in functional capacity. This change however is more apparent, or less noticeable at various points of the life span. While development advances with age, these two may not always be dependent upon each other. Development may occur at faster or slower rates and may differ between individuals of the same age. Advancement in age does not necessarily proceed with an equivalent advancement in development (Haywood and Getchell, 2005, pp.4-5).

Motor development is the advancement of movement abilities (Haywood and Getchell, 2005, p.5) and concerns issues that are related to motor learning and control or both (Magill, 2007, p.3). Motor development is usually assessed in terms of age of achievement of milestones. Evaluation of milestone's performance however, consists in observing not only what children do, but how and with what level of development they do it (Wijnhoven et al., 2004). Nevertheless, not all movement changes can be characterised as development. Relatively permanent movement changes related to experience rather than age are described by the term motor learning (Haywood and Getchell, 2005, p.5).

In the prenatal phase motor development is influenced by several genetic and extrinsic factors. While genes direct a precise course of development, the extrinsic factors influence this process in a positive or negative way. Therefore, prenatal abnormalities may arise from both genetic and extrinsic factors (Haywood and Getchell, 2005, p.33). Postnatal development is the continuation of prenatal growth and may be influenced by a number of hereditary and extrinsic factors. Such factors are gender, weight, height, physiological maturation and extrinsic factors (i.e nutrition) (Haywood and Getchell, 2005, p.33, Malina et al., 2004, p.209).

The factors proposed to be responsible for the individual variations in the speed of motor development are poorly understood. As motor behaviour progresses, reflex and generalised movements become replaced by differentiated, specialized and integrated movements. Both the capacity and rate of acquisition of skills increase progressively as the child becomes older. Some movements that are mastered in the first few years of life contribute to

the self-sufficiency of the child whereas others relate to various forms of play (Shepard, 1982, p.108). Development is sequential, in terms that, one step leads to the next in a systematic and irreversible manner. Individuals undergo knowable patterns of development. However, development always results in a group of unique individuals (Haywood and Getchell, 2005, p.5). As such, during motor development, improvement of motor performance especially in later childhood is usually governed by three factors:

- a) development of the neurologic, neurophysiologic and mechanical aspects involved in a specific movement,
- b) a more sufficient use of the existing systems through more effective filtering mechanisms and elimination of unnecessary operations,
- c) interaction of the above with progressive organisation of a neural network (Shepard, 1982, p.118).

Following this, children between the ages of 7 and 8 years, are frequently unable to adequately perform tasks which require a great amount of coordination, while earlier instruction might result in either poor performance or total failure (Shepard, 1982, p.118). Between the ages of 8 and 12 years, the motor tasks being performed by children are relatively general in nature and do not demand a high level of coordination. In adolescence individuals usually perform adequately in tasks which are related to their interest (Shepard, 1982, p.122).

2.2.1. Gender

Gender is a major factor in the timing and the extent of growth. Gender differences are non significant in early childhood, however as age progresses males and females demonstrate different developmental characteristics (Haywood and Getchell, 2005, p.38). Controversy exists as to whether girls in their first year of age have a slighter advantage in motor performance compared to boys. After the age of 8 years, girls are usually better in fine motor tasks, motor aspects of verbal function and other tasks that involve rapid perception or frequent shifts of attention. Boys, on the other hand, outperform girls in gross motor tasks (Shepard, 1982, p.124).

2.2.2. Height

Height follows the sigmoid pattern of growth. There is a rapid increase in infancy, tapering off to steady growth during childhood, and another increase during the adolescence growth spurt followed by a tapering off until the end of growth (Haywood and Getchell, 2005, p.39). On average girls reach their peak height velocity during the adolescent growth spurt at around the age of 12, while significant increases occur until the age of 16. Boys reach their peak height velocity later at around the age of 14, while a notable increase may occur until the age of 18 (Shepard, 1982, p.124).

2.2.3. Weight

Weight during development also follows the sigmoid pattern of growth. However, contrary to other genetic factors, weight can be more influenced by extrinsic factors such as diet and exercise or disease. Peak weight velocity follows peak height velocity. The growth of various lengths and breadths can sometimes reach peak velocity prior to peak height velocity however this growth always precedes the peak weight velocity (Haywood and Getchell, 2005, pp.39-40). Normal weight from the moment of birth plays a significant role in the child's development, since abnormal birth weight (i.e low) has been related to performance deficits of children during gross and fine tasks as well as on tests of muscular performance (Malina et al., 2004, p.209).

2.3. Physiological Maturation

Physiological maturation is the developmental process which leads to a state of full function. Chronological age, body size growth and physiological maturation are interrelated, however each one can proceed in its own time (i.e an individual may be small sized but may be very mature for the given age). The appearance of secondary sex characteristics formulates the beginning of maturation. These characteristics may appear early in individuals who are early maturers or later in individuals who are late maturers. In girls, secondary sex characteristics appear earlier than in boys, since girls enter the adolescent growth spurt sooner. Furthermore, individuals who mature earlier than others are likely to be stronger and more coordinated (Haywood and Getchell, 2005, p.42).

2.4. Extrinsic Factors

Extrinsic factors may play a significant role during prenatal and postnatal growth. These factors may influence body's metabolism. During periods of rapid growth, after birth and in early adolescence, growth is particularly sensitive to environmental alterations. The term catch-up growth best describes the influence of extrinsic factors to overall body growth. An individual might experience catch-up growth after a period of severe malnutrition, or disease (Haywood and Getchell, 2005, p.43). For example, a child who might experience a physical disability, will change his or her view for future experiences (i.e involvement in a physical education programme), which he or she wouldn't experience if the disability was not present in the first place (Lerner, 2002, p.153). After treatment, growth rates increase until the individual catches-up with the expected growth during that period. The growth rate however, depends mainly on the timing, duration and severity of the influential extrinsic factor (Haywood and Getchell, 2005, p.43).

2.5. Models of motor development

Newell's model of 1986 (Newell, 1986) suggests that movements arise from the interaction between the organism, the environment in which movements occur and the task to be performed. Any change in these three factors, results in a change in particular movements (Haywood and Getchell, 2005, p.6).

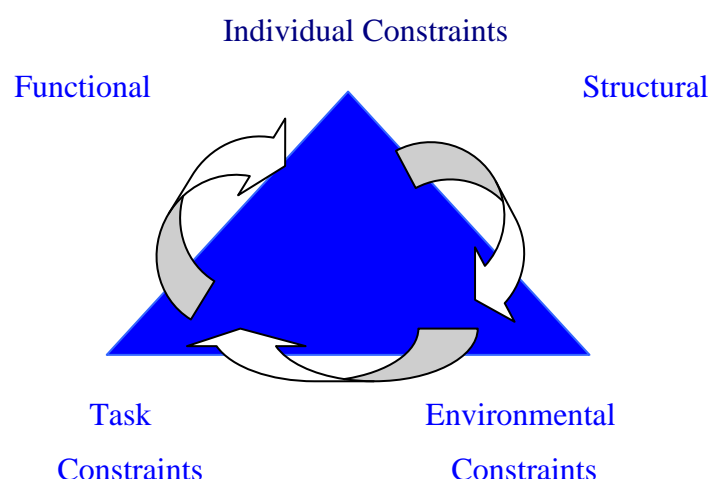


Figure 1. Newell's model of constraints (Piek, 2006, p.61)

This model describes constraints (i.e physical and mental characteristics of the individual, which might be structural, functional and environmental or task specific) like “limits” which may restrain movement, but which simultaneously authorize other movements. Constraints may restrain and guide movement to a particular time and place in space; that is they give movement a specific form (Haywood and Getchell, 2005, p.7, Piek, 2006, p.62). Structural constraints may change in a slow manner as age progresses. Such constraints may be the height, weight, muscle mass and leg length. On the other hand, functional constraints change rapidly and may be aspects of motivation, memory and attention. Environmental constraints are external to the body and are characterised as physical or sociocultural. Examples of environmental constraints include temperature, humidity, gravity and others. Task constraints are also external to the body. These include goals, rules and equipment. Newell’s model is very helpful in the study of motor development, since the environment in which individuals perform tasks is subject to a continuous change (Haywood and Getchell, 2005, pp.7-8).

2.6. Theories of Motor Development

2.6.1. Maturational Perspective of Motor Development

The maturational perspective explains developmental changes as a function of maturational processes that control or dictate motor development. This theory implies that motor development arises as an innate or internal process driven by a biological or genetic time-clock (Haywood and Getchell, 2005, p.17). From this perspective, development of movement coordination is brought from changes in the constraints imposed upon the organism-environment system. In particular, these constraints may act at certain developmental times, as limiting factors in the emergence of new motor behaviours, in the mastering of new actions or in the sustainability of highly skilled actions (Savelsberg et al., 2003, p.193).

2.6.2. Information Processing Perspective of Motor Development

Motor skills acquisition has been influenced by the information processing framework of the 1950s and 1960s and the subsequent development of general cognitive perspectives of action (Newell, 1991). The information processing perspective is the one most often associated with motor behaviour and development. This theoretical approach implies that the brain acts like a computer, inputting information, processing it and outputting movement. The process of motor learning and development is thus described as computer alike operations that occur as a result of external stimuli (Haywood and Getchell, 2005, p.19). One of the major criticisms of this theory is in regard to the inability of this theory to provide adequate explanation for the control of movement in less than one reaction time (McMorris, 2004, p.153, Schmidt and Fitzpatrick, 1996, p.195).

2.6.3. Ecological Perspective of Motor Development

A new approach regarding motor development appeared in the 1980s, called ecological perspective. This approach stressed the interrelationship between the individual the environment and the task (Haywood and Getchell, 2005, p.19).

Traditionally ecological perspective has two branches, one concerned with motor control and coordination (Dynamic Systems) and the other with perception (Perception-Action) (Haywood and Getchell, 2005, p.20). This theory however is not without its critics. McMorris, (2004, p.155) argues as to how ecological psychologists could explain the fact that comparatively large changes in movement cannot be made in less than one reaction time.

2.6.3.1. *Dynamic Systems Approach*

Dynamic systems approach suggests that coordinated behaviour is “softly assembled” rather than “hard wired”. This means that the interacting systems within the body act together as a functional unit to enable walking when needed. Without a hard-wired plan, there is a greater flexibility in walking, which allows individuals to adapt their walking pattern to many different situations. This process is called spontaneous self-organisation of body systems. As movement is the result from the interaction between the

constraints, any change in the constraints will result in a change in the movement (Haywood and Getchell, 2005, p.20). The dynamic systems theory implies that the number of biomechanical degrees of freedom of the motor system is dramatically reduced through the development of coordinative structures or temporary groups of muscle complexes (Turvey, 1990). The least complexity of the motor system encourages the development of functionally preferred coordination or "attractor" states to support goal-directed actions. Within each attractor region (the "neighborhood" of an attractor) system dynamics are highly ordered and stable, leading to consistent movement patterns for specific tasks. Variation between multiple attractor regions, however, permits flexible and adaptive motor system behavior, encouraging free exploration of performance contexts by each individual (Kamm et al., 1990).

An important motor development concept originated from the dynamic systems approach is the notion of rate limiters or controllers. Individuals might learn new skills when the slowest of the necessary systems for that skill to be performed, reaches a certain point. Such systems are known as rate limiters or controllers. The dynamic systems approach, contrary to the maturational perspective, suggests that different systems might be rate controllers for various skills (Shumway-Cook and Woollacott, 2007, p.14). Another very important feature is the notion that this theory applies across the life span, in contrast to the maturational theory which examines motor development until the endpoint of maturation. This feature is critical as the theory underlines that when an individual's system declines to a certain point, a change in motor development might occur (Haywood and Getchell, 2005, p.20).

2.6.3.2. Perception-Action Approach

The perception-action approach suggests that there is a close interrelation between the perceptual system and the motor system. Perceptual control depends on the detection of the relevant perceptual information as well as on the functionality of the actions. In many situations, the available perceptual information from the environment for controlling and action is multimodal (Bertenthal, 1996). For this approach, therefore, perception cannot be studied independently of movement if the result has to be ecologically valid.

Additionally, the individual must be studied in the environment in which movement is to be performed. Gibson, during 1960s-1970s introduced the term “affordance” to describe the function an environment object provides to an individual; this is related to the size and shape of the object and the individual within a particular setting (Shumway-Cook and Woollacott, 2007 , p.16). The implications of this idea for motor development is that affordances change as individuals change, resulting in new movement patterns. Growth may play a significant role here as enhanced movement capabilities may allow for new actions (Haywood and Getchell, 2005, p.22).

To summarize, researchers have provided equivocal evidence for the use of every theory. The information processing theory which suggested that the central nervous system performs almost limitless calculations on stimulus information to determine the speed and direction of both the body and the moving objects, is believed to be a rather conceptual framework than a specific theory (Salthouse, 1992, p.261). The information processing theory clearly identifies that such calculations are used to anticipate future positions. On the contrary, the perception-action theory implies that the individual becomes environmentally aware by constantly moving the eyes, head and body. Such an activity constantly provides space and time information (Haywood and Getchell, 2005, p.22). Although the ecological approach of motor development has expanded the knowledge in regard to the organism and the environment it provides less information as to how the nervous system lead to this interaction in the first place (Shumway-Cook and Woollacott, 2007 , p.16).

2.7. Motor development and the Role of Brain Function

The development of the human brain is a continuous and long-lasting process. At the age of approximately 30 years of age, the nervous system takes its final configuration. The shaping of the nervous system is guided by neurochemical processes and neural activity. A considerable part of the brain development occurs during childhood where the organ continually remodels itself (Hadders-Algra, 2004).

These neurological adaptations during childhood have major clinical implications. The noticeable developmental changes of the brain may produce

significant implications for the prediction of developmental disorders at an early age. However, these changes can also induce a desertion of dysfunctions often observed at an early age. The reverse is also possible: children can be free of dysfunctions at an early age but grow into a functional deficit as age increases because of the age-related increase in the complexity of the neural functions (Hadders-Algra, 2004). From a maturational point of view, genetic disorders may lead to focal cortical damage and consequently to selective cognitive, motor, or perceptual disorders. The symptoms of these disorders would first become evident at the normal age of maturation of the regions concerned. However, recent evidence suggests that there are very few, if any, developmental deficits genetically originated that affect only one or two specific regions of cortex (Johnson et al., 2002).

A contrasting perspective, assumes that postnatal functional brain development involves the process of organizing the patterns of interregional interactions. Genetically originated developmental disorders usually involve disruption of the typical biases and interactions between regions that give rise to adult patterns of cortical functional specialization. Symptoms would then be evident from the moment of birth, but these will become pronounced as the child grows older and abnormally interacts with the environment during several tasks (Johnston et al., 2002).

2.8. Motor Control and Skill Learning

Sensory and central contributors to motor control modelling are the closed-loop and open-loop systems. Closed loop systems are fundamental for many cases in the study of motor control, especially for those that a system needs to control itself (Schmidt and Lee, 2005, p.126). Closed-loop movements are usually adopted for learning novel tasks and very accurate visually guided aiming, which allows for more corrective movements at the end of the trajectory (Smits-Engelsman et al., 2003).

The close-loop model of motor control systems such as Bernstein's (1967) provides the logical sequence of a control system. In this model, a number of aspects are considered as obligatory needs for a system to act voluntary. These aspects include:

(a) an effector or motor activity which is regulated along a given parameter,

- (b) a control element which conveys to the system the required value of the parameter for regulation,
- (c) a receptor which perceives the actual course of the value of the parameter and signals it to
- (d) a comparator device which perceives the discrepancy between the actual and required values with its magnitude and sign;
- (e) a recoder then encodes the data provided by the comparator device into correction impulse which are transmitted by feedback linkages to
- (f) a regulator which controls the function of the effector along a given parameter. The system requires the constant comparison of the required value of the parameter with the actual course. Any discrepancy between the two is then translated into the necessary correction signal.

Even though Bernstein's model (1967) is presented with a number of clearly articulated strengths, it does not explain adequately what is observed in relation to skills (Au, 1984). In the 70s, understanding how skill development in infancy and childhood occurred was an obvious problem. A potential solution to this problem came for Schmidt's model (1975), who argued that although a number of closed-loop postulations to explain motor skills learning and performance phenomena may existed at that time, these suffered from logical explanations and derived from predictions which were not supported by empirical evidence.

Schmidt's theory concerned the development of general motor programmes and response specifications. His theory used the concept of schemata and was particularly concerned in motor response schemata. Four sets of information formed the motor response schemata:

- a) the initial conditions of the limbs and the state of the environment,
- b) response specifications for a motor programme,
- c) sensory consequences and
- d) response outcome or knowledge of results.

Also, Schmidt's theory suggests that there were two states of memory involved, namely "memory trace" and "perceptual trace". Memory trace is formed from a function of knowledge of results and practice and formulates a modest motor programme which is responsible for initiating movement.

Perceptual trace is formed from past experience using feedback, represents the sensory consequences of human movement and is analogous to recognition memory. The individual, then, evaluates the feedback from the actions against the perceptual trace and on the basis of this evaluation fundamental modifications are made. Thus, “perceptual trace” is strengthened by feedback and by knowledge of results. Learning is the results of feeding vital error information to the schemata. Schmidt suggests that learning results in a recognition schema, analogous to the recall schema. The recognition schema is related between the “a”, “c” and “d” sets of information, mentioned previously. The resulting schema allows for a reproduction of the sensory consequences of the action which are likely to ensure the desired outcome. He also considered that learned motor sequences are controlled together by a motor programme and by an insource reference schema that represents the sensory consequences of an action reaching a desired environmental goal. This motor programme ensures that initiation and execution of the motor sequence will occur and can operate either in an open-loop fashion or with the assistance of regulatory proprioceptive feedback loops. The internal reference schema or subjective reinforcement then enables the individual to identify his or her performance errors and make analogous adjustments.

Schmidt (1975) assumed that there are generalised motor programmes for a given class of movement. His theory provided a logical meaning of how movements, which were not practised before by an individual, initially generated. This theory provided the grounds in motor learning studies for understanding that any adjustments-modifications of motor behaviour were a consequence of experience (Au, 1984).

2.9. Motor Skills Acquisition

Skills are fundamental to the development of mastery and control over the environment. The ability to meet the environmental demands and reform the environment is closely related to the individual’s competency on a range of skills (Au, 1984). A skill is an individual’s ability to achieve performance tasks under a variety of conditions. In the study of motor skills, the tasks are considered motor problems that are to be achieved by the execution of a sequence of appropriately organised movements. Thus, a person’s skill is

expressed by some level of control over a directed movement (Newell, 1991). The greater the ability to analyze and figure out the problems during the process of movement the greater the level of the skill will be (Higgins, 1991).

Illingworth (1970) suggested that the acquisition of various skills is dependent upon the maturation of the nervous system. Practice alone cannot result in a child who learns certain skills until his or her nervous system is correspondingly matured. On the other hand, motor skill delays could be caused by scarcity of enough opportunity to practise skills when maturation has occurred (Au, 1984).

“Motor learning” emphasizes on the acquisition of motor skills, the performance enhancement of learned or highly experienced motor skills, or the reacquisition of skills that are difficult to perform or cannot be performed because of injury, disease and the like (Magill, 2007, p.3). Acquisition of skills is the attainment of those practice-related capabilities that contribute to the increased likelihood of goal achievement. A “perceptual-motor skill” is the skill whose goal is non symbolic. Perceptual-motor skills also seem more tied to specific forms of expression. Non symbolic outcomes seem to depend on specific associations between stimuli and reaction. Perceptual motor skills are learned through practice (Rosenbaum et al., 2001).

“Motor skills” are defined as activities or tasks that require voluntary head, body and/or limb movement to achieve a specific purpose or goal (Magill, 2007, p.3). A motor skill requires part of the body to move voluntarily, unlike other natural skills which may be cognitive and involve involuntary actions (Magill, 2007, p.5). According to which primary muscle group is used, motor skills can be classified as “*gross*” and “*fine*” motor skills. “*Gross*” motor skills, which are commonly known as fundamental motor skills, require large musculature in order to be performed. Gross skills however require less precision than fine motor skills. “*Fine*” motor skills on the other hand require a substantial control of the small muscles, especially those involved in the eye-hand coordination, and a high degree of precision in hand and finger movements (Magill, 2007, p.7). Figure 2 summarises the components of gross and fine motor skills.

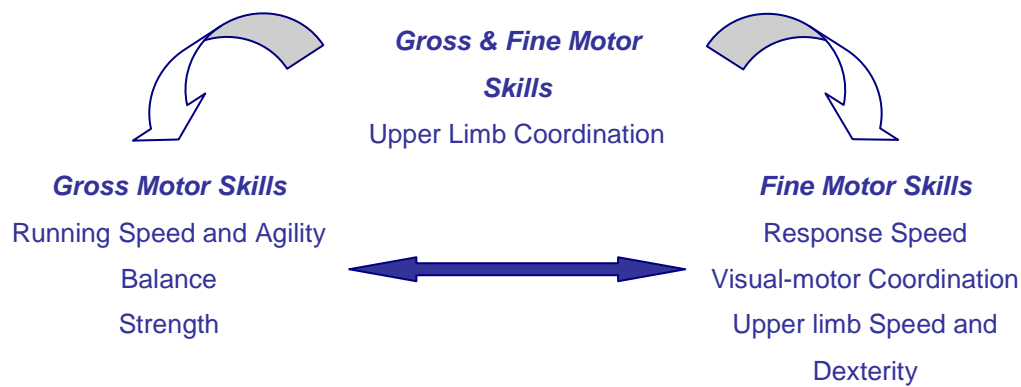


Figure 2.Components of gross and fine motor skills (Bruininks, 1978)

Another type of classification for motor skills exists according to where the skill begins and ends. “*Discrete*” skills are those skills that have a definite beginning and end location, and are typically simple, one movement skills. “*Continuous*” motor skills on the other hand are the skills that have a random beginning and an end location and usually involve repetitive movements. Furthermore, some skills require a series of discrete movements. Such skills are known as “*serial*” motor skills. These skills involve repetitive movements characteristic of continuous skills and the definite beginning and end locations of each movement (Magill, 2007, p.9, Schmidt and Lee, 2005, pp.20-21).

In the environmental context motor skills can be distinguished in closed and open motor skills. A closed motor skill refers to skills where the relevant environmental context features are stationary or predictable (Hays, 2006, p.130). In contrast, open motor skills refers to skills that an individual performs in an environment in which the surrounding features are constantly changing, so that the individual cannot plan the entire movement in advance (Magill, 2007, p.10, Schmidt and Lee, 2005, pp.21-22).

2.10. Planning and Execution of Movement

Movements are also an integral part of motor skills however, these two should be distinguished. The term movement indicates behavioural characteristics of the head, body and/or a specific limb or combination of limbs (Magill, 2007, p.5). Three distinctive reasons between movements and motor skills are:

- a) Individuals should move to perform a motor skill however different

- individuals may move in different ways to achieve the same action goal.
- b) Individuals differ in physical features that limit the movement characteristics they can produce to perform a skill.
 - c) Unlike motor skills which can be measured in terms of performance (i.e distance, length), movements are evaluated by measures relative to the body's characteristics (i.e kinematic, kinetic) (Magill, 2007, pp.6-7).

There is a three-level hierarchy in the planning and execution of movement (Figure 3). On the *lowest level* is the spinal cord, composed of primary neural circuits made of motor neurons (afferent to the muscles spindles, as well as responsible for the muscles activation or inhibition) and inter-neurons. The spinal circuits encode stretch and retracting arm movements and rhythmic movements of legs and arms involved in the locomotion, i.e central pattern generators. The *second level* is the brain stem, which is responsible for the coordination of muscle activity across the spinal circuits and for low-level motor response to somato- and visuo-sensory feedback (e.g for postural adjustments and compensation of head and eye movements). The *third level* corresponds to three cortical areas of the brain, the primary motor cortex, premotor cortex, and supplementary motor area (Cunnington et al., 1996). The two latter areas play an important role in the coordination and planning complex sequences of movements. The primary motor cortex contains a motor map of the body. It is divided into subparts which each activates distinct parts of the body (Billard, 2001).

In addition to these levels, another level of motor control is provided by the cerebellum and the basal ganglia. The main functional difference between these two regions lies in their connectivity with the rest of the motor circuit. Parts of the cerebellum have direct afferent connection to the spinal cord and efferent connection to the brain stem, and periprocal connections with the premotor and supplementary motor cortexes. In contrast, the basal ganglia have no direct connection to the spinal cord and very few with the brain stem, while it projects to regions of the prefrontal association cortex (Doyon et al., 2009). The basal ganglia are thought to play a role in the high-level cognitive aspect of motor control (planification, execution of complex motor strategies) as well as in gating all types of voluntary movement. The cerebellum has

been shown to participate in motor learning (Houk et al., 1996) and in particular in learning the timing of motor sequences (Billard, 2001).

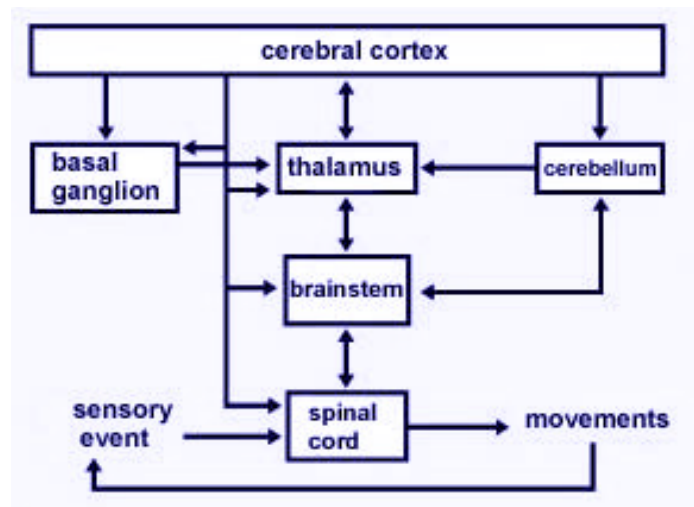


Figure 3. Schematic representation of planning and execution of movement. (Abernethy et al., 2005, p.219).

2.11. Coordination

Bodily movements occur in the context of the everyday functioning of people while realizing specific task goals. Such movements involve the participation of multiple joints and limbs. Turvey, (1990) defined coordination as the patterning of head, body and limb movements relative to the patterning of environmental objects and events (Magill, 2007, p.83). This definition implies that coordination involves patterns of head, body and/or limb movements. With reference to a movement pattern associated with the performance of a skill, coordination refers to the organisational relationship of movement characteristics of the head, body and limb involved in the performance, regardless of the skill level of the performer (Schmidt and Lee, 2005, p.244).

Humans seem to be able to perform coordination actions almost effortless. Countless activities of everyday life require the limbs to perform different actions at the same time. While some tasks (i.e. throwing) may be performed by the upper and lower limbs when acting simultaneously without difficulty, other tasks may be more difficult to perform, because of the interference between effectors. Examples of such tasks include patting the head while rubbing the stomach. Such evidence suggests that there are inter-limb coordination limits which may in one hand support activities such as

locomotion, but which on the other hand tend to obstruct more arbitrary skills that require other patterns of coordination (Schmidt and Lee, 2005, p.244). Evidence suggest that in order to carry out a complex motor pattern, the central nervous system has to allow the rapid and efficient process of afferent information (Bonifacci, 2004). These situations involve coordinating a number of different motor programmes simultaneously and activating these in order to provide the appropriate descending control to the actuators involved (Staudte et al., 2000). During action, the body parts are coordinated which means that they are related to one another and to the surrounding surfaces (Beek et al., 1995).

Coordination therefore, is an a posteriori result of pattern formation or physical self-organization (Kelso, 1994). Self-organization suggests that coordinated movement is the product of complex organizations, composed of large number of interacting essentials and which may in consequence adapt in a flexible manner to internal and external changes by adopting a different coordination pattern without any explicit prescription of this pattern (Beek et al., 1995).

Coordination of movement, however, is governed by a system of constraints originating from the musculoskeletal and neural systems. Some of these constraints are easily discriminated, while other constraints are less obvious. These constraints of coordination, whether perceptual, cognitive or musculoskeletal, are mediated by the integrative action of the central nervous system (Carson and Kelso, 2004). Evidence suggests that the neuroanatomical characteristics of the muscles involved in movement profoundly influence the stability of sensorimotor coordination (Carson and Kelso, 2004). Sensorimotor coordination demands that specialised neural and musculo-skeletal systems are organised harmoniously to generate task-specific functional behaviour (Byblow and Carson, 2004).

Carson (1996) suggested that any change in limb's posture, that results in modifications of the lengths and orientations in the muscles engaged during a task, have predictable and reliable effects on coordination stability.

Any changes in muscle strength, such as those after training, may have a corresponding influence upon the stability of sensorimotor coordination. Subsequently to training, the level of cortical input to the spinal motor neurons, necessary to generate a particular degree of muscle activation or joint torque, is usually less than that required before training (Carson and Kelso, 2004). The engagement of muscles and postural transitions, different to those that intent to produce patterns of movement and which differ from those demanded by a coordination task, subsequently implies a deficit in the accuracy and stability of performance (Carson and Riek, 2001).

The simplest kind of coordination is linear superimposition where the motor programs may be executed in parallel without affecting each other. Then again these motor programmes may systematically interact, causing constraints to one another (Staudte et al., 2000). A more complex case of motor coordination is the concurrent execution of more than one rhythmic movements by various limbs or limb segments (Grossberg et al., 1997).

Bernstein proposed that a well coordinated movement to be performed requires the nervous system to solve what he called "*degrees of freedom*". This term reflects the number of independent elements or components of the system. Each element is free to vary in specific ways, as in the case of the elbow joint which can move in two ways (i.e flexion and extension). The degrees of freedom problem arises when a complex system needs to be organised to produce a specific result (Magill, 2007, p.84). For example, previous experiments regarding bimanual coordination showed that degrees of freedom may be recruited or suppressed depending on temporal or spatial constraints (Fink, 2000). However, the exact number of degrees of freedom that must be controlled in movements requiring coordination depends upon the level of control. In spite of the level of control needed for any motor skill, the problem of mastering the control when an individual is trying to perform a skill is apparent. Nevertheless, practising a skill-progressing from a beginner's level to a master level- may in turn lead to solving the problems of degrees of freedom for that particular skill. This becomes evident from the alterations of specific movement characteristics when performing that skill (Magill, 2007, p.85).

2.12. Developmental Coordination Disorder

2.12.1. Definitions and Criteria

The ability to move adaptively within one's environment is a fundamental part of daily life that individuals tend to take for granted. However, many presumably simple tasks can be proved frustrating for children who lack the movement competence to function effectively (Mackenzie et al., 2008). These children usually suffer from "*Developmental Coordination Disorder (DCD)*" which is the uncountable failure to acquire age-specific motor skills (American Psychiatric Association, 1994). This disorder has been described in the past by using various terms. Some of these include "clumsiness", "developmental dyspraxia", "motor coordination problems", "sensory integrative dysfunction" "apraxia", "developmental apraxia", "clumsiness", "dyspraxia", "physical awkwardness", "poor coordination", "motor delay" and "movement difficulties" (Henderson and Barnett, 1998, Willoughby and Polatajko, 1995). It is a frequently overlooked developmental problem which can have considerable impact on children's lives as they struggle to plan, organise, and execute what is effortless for so many of their peers. Often associated with soft neurological signs and subdivided into difficulties with motor planning, learning sequences of movement or executing movements, when all three are involved the term dyspraxia is frequently used (Baird and Santosh, 2003).

The terms used to describe DCD, however, usually reflects the disciplinary background of the researcher. Nevertheless, the use of various terms may compromise communication between researchers and clinicians and result in fewer advances in the service provisions for these children (Magalhães et al., 2006).

Two widely used classification systems, the Diagnostic and Statistical manual of Mental Disorders (DSM-IV) (American Psychiatric Association, 1994) and the International Classification of Diseases (ICD-10) (World Health Organization, 1992), have entries for motor coordination problems among children and adolescents and include guidelines for terminology and inclusive and exclusive criteria (Gueze et al., 2001). It has been questioned, however, whether the diagnostic criteria described in the DSM-IV (American Psychiatric

Association, 1994) were appropriate, because they left plenty of room for manipulations and differential interpretations (Henderson and Barnett, 1998).

In particular, the DSM-IV's classification system for DCD (American Psychiatric Association, 1994), which is the most commonly used among researchers, describes DCD as a marked impairment of motor coordination. Specifically, the criteria described in the DSM-IV are as follows:

- A. Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (eg, walking, crawling, sitting), dropping things, "clumsiness," poor performance in sports, or poor handwriting.
- B. The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.
- C. The disturbance is not because of a general medical condition (eg, cerebral palsy, hemiplegia, or muscular dystrophy) and does not meet criteria for a "*pervasive developmental disorder*" (World Health Organization, 1992).
- D. If mental retardation is present, the motor difficulties are in excess of those usually associated with it (American Psychiatric Association, 1994).

In 1994, at an international consensus meeting on children and clumsiness, held in London, Ontario, Canada, the primary focus was reaching a definition and name for the disability. During this meeting, it was agreed that the DSM-IV term "*Developmental Coordination Disorder*" should be used for this disability (American Psychiatric Association, 1994). The same Consensus also described DCD as a chronic and persistent disorder which is characterized by impairment of motor performance, sufficient to produce functional deficits that are not explicable by the child's age or intellectual ability or by other neurological or spatial-temporal organizational disorders (Dewey and Wilson, 2001).

Due to the heterogeneity of children with DCD, the criteria set by the DSM-IV were introduced in order to help researchers and professionals to distinguish DCD cases from other conditions. An ongoing doubt in regard to

the terminology to describe children with poor motor coordination and the use of the selected criteria by the DSM-IV in terms of assessment, validity and practicality is still obvious in the literature, however the term “*Developmental Coordination Disorder*” is the one used more often (Gueze et al., 2001, Henderson and Barnett, 1998).

Several problems manifested around the terminology and diagnosis of DCD up to 1994 were discussed and clearly appraised by the London (Ontario, Canada) Consensus. Nowadays, experts agree that the DSM-IV-Text Revision (American Psychiatric Association, 2000) provides a useful tool with which diagnosis of DCD can be made. However, as the interest from researchers and professionals alike for this particular disorder increases, so does the need to clarify certain aspects of DCD diagnosis, management and treatment (Sugden, 2006). It is proposed that effective treatment and management is founded on clear identification criteria.

2.12.2. Prevalence of DCD

DCD is a global phenomenon that affects a significant proportion of children. It has been estimated that 5-10% of children in North American and 6-8% in Northern European countries are affected by DCD (Kadesjo and Gillberg, 1999). The prevalence of DCD is usually identified between the ages of 6-to-12 years. While APA has included the above percentages in the DSM-IV (American Psychiatric Association, 1994) the prevalence globally may differ according to gender, severity, culture and means of assessment. It also appears that DCD is more frequent in boys than girls with reported ratios ranging from 2:1 (Sugden and Chambers, 1998) to 4:1 (Kadesjo and Gillberg, 1999). Furthermore, due to the heterogeneity of the symptoms experienced by children with DCD and the different methods to assess the condition worldwide, it is difficult to estimate the exact percentage of children who are affected by subtypes of DCD (Dewey and Wilson, 2001).

The estimation of DCD prevalence has always been problematic. Cut-off points and related assessment instruments have been heavily debated. Nevertheless, the agreement between the DSM-IV and the ICD-10 for certain points in their systems provide a useful tool for these areas. The assessment of Criterion A can be made with a recognised normative-referenced test with

cut-off points. Criterion B assessment may be fulfilled with the use of a criterion-referenced test completed by someone who knows the child well (Wright and Sugden, 1996).

Children with DCD may be found in many settings. Missiuna et al., (2004), report that there is always one or two students in every classroom that can be a real puzzle. She notes that independently of their intellectual ability and active participation in academic requirements, these children may struggle with certain skills.

Some years ago researchers estimated that the prevalence of DCD was around 10-19% (Henderson et al., 1992, Smyth, 1992). Later evidence suggest that the DCD prevalence is between 5-10% (Kadesjo and Gillberg, 1999), while an exact percent of DCD is estimated at 6.4% (Hamilton, 2002). Smaller percentages have been reported which were estimated around 2.4%, but as DCD prevalence estimation is highly dependent on modes of assessment and cut-off points, this study may have missed a couple of DCD cases (Petersen et al., 2006). Recently, a study revealed a 1.8 % of DCD prevalence, with a strict use of the DSM-IV criteria (Lingam et al., 2009). However, this study utilized only 3 subtests of motor tests that originally derived from the Movement - ABC (Henderson and Sugden, 1992) to predict severe DCD cases within the sample, which in turn may have provided only a few cases of DCD, while more may not have been missed if a full norm-reference test was used.

Overestimation or underestimation of prevalence rates is a serious problem that may be avoided by appropriate cut-off scores for each test. Cut-offs are important to consider as they have a mediate impact on classification and intervention planning (Wright and Sugden, 1996). Holsti et al., (2002) reports that, contrary to the International Classification of Diseases 10 (ICD-10) that uses a cut-off of 2 Standard Deviations (SD) below age norms for the diagnostic category “specific developmental disorder of motor function.” (World Health Organization, 1992), it is standard clinical practice to use a -1 SD cut-off score (i.e., performance below the 15th percentile) on standardised motor assessments for diagnosing DCD in children. In addition the authors stated that the use of a strict diagnostic criterion prevents from “overlabeling”.

2.12.3. Co-occurrence of DCD with other disorders

Studies of the past decades have suggested that children with reading difficulties (i.e dyslexia), quite often, present simultaneous problems in attention (i.e ADHD) and acquire movement skills which are fundamental for them in order to function at home or at school (Figure 4) (Kaplan et al., 1998, Miller et al., 2001).

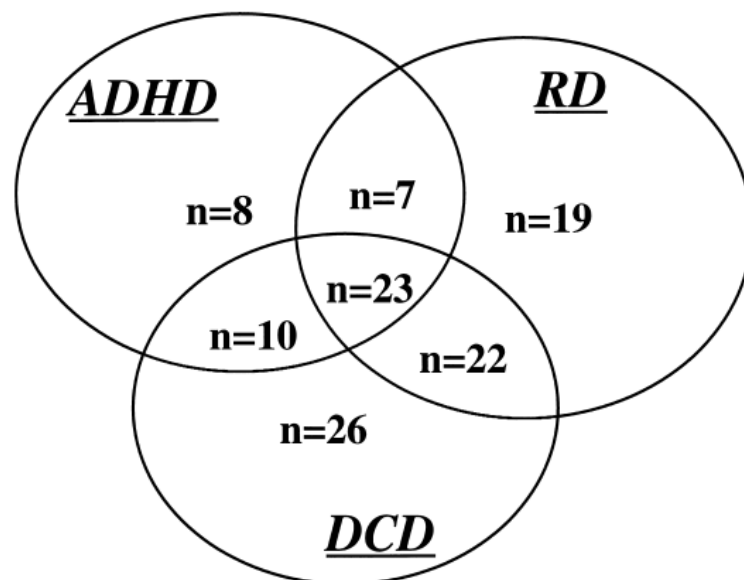


Figure 4. Co-occurrence of three developmental disorders (Kaplan et al., 1998)

Kaplan et al., (1998) also stated that even though it is one set of difficulties that appears to be more evident than others, it is rarely an isolated problem. This group of researchers has also suggested that the co-occurrence of various disorders may actually be manifestations of a single underlying aetiology. Nevertheless, since diagnosis, management and treatment are different for each disorder, knowledge of the exact mechanisms that underlie the co-occurrence between DCD and other disorders would be of great value in order to differentiate groups of children with various developmental disorders.

In Scandinavia, the terms “minimal brain dysfunction syndrome” (MBD) and “motor perception dysfunction syndrome” (MPD) have been used more specifically to characterize groups of children who are not mentally retarded, are not cerebral-palsied, are presented with attentional deficits and have major or minor neurological signs or perceptual difficulties. These terms however,

have received much dispute regarding their use in Scandinavian countries (Gillberg, 1983, Gillberg et al., 1982). At that time, Gillberg's group believed that children with MBD will grow out of their neurological or neurodevelopmental dysfunction, and reported that a 25% of severe MBD cases and more than 50% of mild-to-moderate MBD cases will possibly grow out of their neurological deficit. Similar results were presented for children with MPD and attention deficit disorder. This, however, was not the case for behavioral and school-achievement problems, where most of the children with MBD displayed signs of maladjustment at the age of 10.

Thereafter, the term "*deficits in attention, motor control and perception*" (DAMP) (Gillberg, 1986) started to receive referral in the Scandinavian counties. DAMP is a syndrome which characterizes children with a combination of attention deficits and clumsiness (Kadesjo and Gillberg, 1998). This term, however, has accepted severe criticism by other experts in the field who reported that the DAMP term was too vague (Rydelius, 2000). In 2003, Gillberg published a review paper where a revision of the definition of DAMP is presented (Gillberg, 2003). The new definition is as follows: (a) Attention Deficit Hyperactivity Disorder (ADHD) as defined in DSM-IV; (b) DCD (Developmental Coordination Disorder) as defined in DSM-IV; (c) condition not better accounted for by cerebral palsy; and (d) IQ should be higher than about 50. Strong criticism of the DAMP however, has continued even after the revision of its definition (Martin et al., 2006).

Prevalence rates of co-occurring disorders (i.e between DCD and ADHD, DCD and reading difficulties), have been examined by various studies. Kaplan et al., (Kaplan et al., 2001) found that out of 107 children with ADHD, 29 (17.1%) children also met the criteria for DCD. This study also revealed that children who were diagnosed with DCD combined with reading difficulties or ADHD had a greater chance of displaying more than one overlapping disorders. Higher prevalence rates of co-occurring DCD and ADHD (47-50%) and sub-threshold ADHD (47%) were found in other studies (Kadesjo and Gillberg, 2001, Kadesjo and Gillberg, 1999). In terms of learning problems, Dewey et al., (2002) reported that children with DCD and ADHD displayed significantly poorer performance on reading writing and spelling scales

compared to the control group, even when IQ differences among groups were controlled. Gaines and Missiuna (2006) also found a co-occurrence of DCD with speech/language problems in a sample of 5-to-6 year old children.

In a study by Kirby et al., (2007), a 35 % of children with ADHD had parent-reported movement problems or were considered at risk for movement disorder with symptoms corresponding to the criteria for DCD. Other researchers have reported even higher prevalence rates of co-occurring DCD and subscales of ADHD. Another study revealed that the overlap between DCD and ADHD –Predominantly Inattentive was 64.3% and 58.9% between DCD and ADHD-Combined, whereas a 11% prevalence was reported for children with DCD and ADHD-Predominantly Hyperactive-Impulsive (Watenberg et al., 2007).

Studies that have followed children with DCD and ADHD suggest that these children are also at risk for a number of psychiatric and personality disorders. Hellgren et al. (1994) found that more than half of the adolescents with DAMP also displayed psychiatric or personality disorder symptoms. A follow-up of the same adolescents at 22 years of age revealed that 58% of the ADHD with DCD group had a poor outcome. The group also presented antisocial personality disorder, alcohol abuse, criminal offences, reading difficulties and low educational level (Rasmussen and Gillberg, 2000).

Previous research therefore, suggests that DCD is associated with a number of disorders, including ADHD, reading difficulties, emotional and psychiatric disorders.

2.13. Characteristics of Children with DCD

Children with DCD is a divert sample in terms of dysfunction. These dysfunctions are usually subdivided in three areas (Barnhart et al., 2003):

I. *Gross motor dysfunctions*. These among others, include awkward running patterns, frequently falls, dropping of things and difficulty in following sequential movements. As a result, these children perform less well on sporting activities (Dewey and Wilson, 2001, Hay and Missiuna, 1998).

II. *Fine motor dysfunctions*. Children with DCD appear to have problems with movements and tasks which require dexterity and planning such as,

handwriting, gripping, and dressing as well as with buttoning and unbuttoning their clothes and tying their shoelaces (Hay and Missiuna, 1998).

III. *Psychosocial dysfunctions*. As a result of their dysfunctional gross motor behaviour these children demonstrate reduced levels in sporting activities, low self esteem and confident and less social interaction with their peers (Skinner and Piek, 2001).

Even though every child with DCD is different, these children generally share common characteristics. They are demonstrating clumsy movements and poor coordination and often complain about falling, tripping or bumping into things. Their motor problems can affect gross motor skills, fine motor skills or both. Motor problems are more evident when performing skills such as catching, throwing and jumping. In school, these children demonstrate problems with academic achievement in which some or all areas of learning are affected. This condition may also lead to secondary problems of psychological adjustment (Green et al., 2006). Examples of the stress under which these children function include feelings of incompetence, frustration, depression and anxiety (Polatajko, 1999, p.127). Consistent evidence also suggests that the motor characteristics of children with DCD which are most commonly observed include: significantly lower reaction, movement and speed, timing control difficulties, force control difficulties, variability of performance in various tasks, vulnerability of perturbations of movement. Also, inability to adjust to movement changes, tendency to rely on vision to control balance and posture, tendency to rely on proximal muscle control to achieve balance tasks, poor intensensory integration with respect to mapping visual and proprioceptive information, utilization of different neuromuscular strategies to achieve bimanual coordination and a tendency to demonstrate deficiencies in motor control as age progresses has been observed. The latter seems to be related to a central nervous dysfunction rather than attributed to a developmental delay (Cermak and Larkin, 2002, p.137).

Motor difficulties experienced by children with DCD tend to be apparent to a child's peer group. Children with DCD tend to be labelled by their peers and excluded from group activities. It has been reported by children with DCD that their condition has: a) prevented them from participating in sporting

activities, b) contributed to pessimistic feelings about themselves, and c) resulted in less self-confidence in regard to physical and social skills (Hellgren et al., 1994). Behavioural and emotional problems, adjustment in the school setting, and other social participation problems have also been reported in the literature (Cantell et al., 1994, Gueze and Borger, 1993, Kadesjo and Gillberg, 1999). As a result, children with DCD are more likely to withdraw from physical activities that involve social interaction (Hellgren et al., 1994).

2.14. Assessment of movement skills

The assessment of movement skills can be made by various tests. Such tests are categorised as norm-referenced or criterion-referenced tests and formal or informal tests.

2.14.1. Norm-referenced tests

Norm-referenced tests involve comparisons between an individual's performance and a normative group (Montgomery and Connolly, 1987). In such tests performance scores are converted to relative scores (i.e., z scores, standardised scores, percentiles). The normative group is a group of individuals whose characteristics are similar to those for whom the test was designed, while norms refer to tabular data or statistics that summarize the test performance of the group (Burton and Miller, 1998, p.92). Norm-referenced tests allow for the determination of an individual's standing relative to his or her peers, and are particularly useful for screening and designing evaluation services and programmes, while they rather assess the functional parameters of the skill than the way the skill was performed (Burton and Miller, 1998, p.93).

These tests however, are presented with some disadvantages. In particular, whether a result of such a test is valid depends upon the appropriateness of the normative group for the individuals being tested. For example, the primary factors used in converting raw scores to relative scores are age and gender, even though that other factors such as height, weight and body composition are also important factors. Furthermore, if a norm-referenced test is used to identify individuals who might need further

evaluation of their skills from certain services, the validity of the critical relative score needs to be established. Additionally, for individuals who score poor on the performance tests of these tests little information may be drawn in regard to what caused the poor performance (Burton and Miller, 1998, p.94). Also, as variability represents the most common movement skill inadequacy among children, many norm-referenced tests rely on mean performance or do not allow for a sufficient number of trials to determine variability. Finally, the assessors experience in conducting such tests may create a random or systematic bias towards the results (Burton and Miller, 1998, p.95).

2.14.2. Criterion-Referenced Tests

Criterion-referenced tests involve the comparison of an individual's performance to a fixed criterion. In such tests, a score is usually represented by a yes-no answer. The performance of the individual is interpreted in absolute terms, although some criterion-referenced tests might be exempted. Such assessments indicate the content of an individual's "behavioural repertory" and are commonly used to certify competency, plan therapy strategies and evaluate progress (Burton and Miller, 1998, p.95).

In movement-related criterion-referenced tests, there are three components: target movement behaviour, task conditions and performance criterion. The items of these tests may be drawn from a physical education or movement activity curriculums, may be based on movement skills task analysis or may characterize the minimum requirements for functional movement in various settings (Burton and Miller, 1998, p.96, Montgomery and Connolly, 1987). Advantages of criterion-referenced tests involve an individualized approach to assessment and intervention. In other words, test outcomes are indicative of what an individual is able or not able to do and not how his or her performance relates to the performance of other persons. Certain items in these tests may also produce knowledge about the deficits that underpin the performance of the individual (Morrow et al., 2005, p.108). However, as with norm-referenced tests, there are certain disadvantages in the use of criterion-referenced tests. These negative aspects suggest that some tasks may not be representative of the specific conditions and criteria usually met in various movement behaviours. Furthermore, problems with the

implementation of specific cut-off scores that define mastery or competency in movement behaviours exist. This is related to the fact that experts on the field often argue as to which performance level constitutes mastery. Finally, the concept of using yes-no answers as a score suggests an “insensitivity” of the test to differentiate the performance of the individual from that of other people, as well as it obstructs valid inference regarding the progress of the individual (Morrow et al., 2005, p.108).

2.14.3. Formal and Informal tests

Formal tests involve uniform conditions and directions (Burton and Miller, 1998, p.99), unlike informal tests which are all the other assessments that cannot be categorized as formal (Burton and Miller, 1998, p.101). All norm-referenced tests are formal, while criterion-referenced tests may be either formal or informal. Thus, norm-referenced tests are particularly useful for screening, making decisions about placing and programme evaluation (Burton and Miller, 1998, p.99). However, formal tests are also presented with certain weaknesses. In particular, aspects of testing situations may not be addressed in the examiner’s manual and therefore may not be standardised. Furthermore, the assessment protocol may require from the examinee to manipulate standardised equipment which may not be appropriate for his or her body measures. Nevertheless, this is a problem which examiners overcome with the use of standardised equipment for each case of assessment (Burton and Miller, 1998, p.100). Additionally, the eligibility of the examiner to provide exact instructions and feedback, according to the test’s procedure, is another issue that needs to be carefully addressed in all formal assessments. Finally, in many formal tests the opportunity of a movement performance assessment in a more “natural” environment is not allowed (Burton and Miller, 1998, p.101).

Categories of informal tests include checklists, interviews, inventories, observations, questionnaires, rating scale and teacher-made tests. These may also be organised in those based on direct observation and those based on indirect information as well as in those that involve the gathering of information with or without the individual’s awareness. The advantage of using these types of tests is that they allow observations to be made in a more

natural environment and assess the effect that this environment may have on movement performance. Nevertheless, the use of informal testing may compromise valid inference since many of the tests of this kind do not come with specific instructions, making it difficult for the examiner to address certain situations that may arise during assessment (Burton and Miller, 1998, p.101).

2.15. Screening for DCD

DCD is a multidimensional disorder affecting various aspects of the human movement process. In the absence of a “gold standard” for the identification of DCD, different assessments may be incorporated while screening for DCD. Such assessments include as mentioned in the previous section norm-referenced tests, criterion-referenced tests, formal tests, informal tests or a combination of these.

2.15.1. Norm-referenced assessment of DCD

2.15.1.1. The Bruininks-Oseretsky test of Motor Proficiency (BOTMP)

The BOTMP originated from the Oseretsky test of Motor Proficiency and is the result of many revisions of the original scale. This test appeared first in Russian during the early 20s, was translated in Portuguese in 1943 and was finally translated in English in 1946 (Burton and Miller, 1998, p.160). Oseretsky initially developed the Oseretsky Test of Motor Proficiency to measure the degree of clumsiness or awkwardness in children (Burton and Miller, 1998, p.28). The test in the original form contained six groups of items (i.e general static coordination, dynamic coordination of the hands, general dynamic coordination, motor speed, simultaneous voluntary movements and synkinesia). The Oseretsky test was modified by several practitioners from 1940-1970s until Bruininks published the still popular Bruininks-Oseretsky Test of Motor Proficiency (Burton and Miller, 1998, p.31). Bruininks based the development of the test partly on the US adaptation of Oseretsky tests of motor proficiency. Despite the similarities in the two tests the revised Bruininks-Oseretsky Test of Motor Proficiency is stronger in content, structure and detail (Duger et al., 1999). According to Bruininks (Bruininks, 1978) the BOTMP was designed to measure various aspects of fine and gross motor

development and its recommended uses include screening, placement, intervention planning, progress evaluation, evaluation of training programmes and motor development curricula, as well as diagnosis of various developmental disorders and research (Burton and Miller, 1998, p.160). The test is administered individually and assesses the motor function of children aged 4.5 to 14.5. The complete battery of tests comprises 8 subtests (46 items) and is proposed to provide an all-inclusive index of motor proficiency. It can also be administered as a separate measure of gross and fine motor skills. The short form of the test comprises 14 items and is a brief and validated measure. The battery of tests includes running speed and agility, balance, bilateral coordination, strength, upper-limb coordination and dexterity and response speed (Bruininks, 1978).

2.15.1.2. The Movement Assessment Battery for Children (M-ABC)

Outside North America the Movement Assessment Battery for Children (M-ABC) developed by Henderson and Sugden in 1992 (Henderson and Sugden, 1992), is the most popular administered test. The M-ABC resulted from the merging of two instruments developed by two independent groups of researchers and clinicians (i.e M-ABC Test and M-ABC Checklist). This test originated from the work of Stott and colleagues in Canada and Great Britain on the Test of Motor Impairment (TOMI). TOMI represented a modification of the Oseretsky tests during late 60s and its original objective was to diagnose subclinical spasticity within the general school population (Burton and Miller, 1998, pp.170-171). A standardised version of the TOMI, which offered reliability and validity data, was published in 1972. Thereafter, the Henderson revision which included four qualitative checklists was standardised in Canada, the United Kingdom and the United States of America. The M-ABC differs from the Henderson revision only in the scoring criteria and task description (Burton and Miller, 1998, p.171). Both the M-ABC test and the M-ABC checklists were designed to complement each other during motor impairment evaluation and can be used to assess children of 4-12 years of age. This test contains eight movement task categories for four age bands (4-6 yr, 7-8 yr, 9-10 yr and 11-12 yr) (Burton and Miller, 1998, p.171). The eight

categories assess three primary motor performance areas (i.e manual dexterity, ball skills and balance), while the assessment duration varies from 20-40 minutes.

The M-ABC Checklist was designed for children between the ages of 5 and 11 years and it can be used both for classroom screening and evaluative purposes for children with movement difficulties. Normative data incorporating a sample of 298 typically developing children aged 6 to 10 years old exist. This checklist is divided into four motor sections and a behavior section. 48 items are included in the motor section and are related to task difficulty:

- (1) child stationary/environment stable,
- (2) child moving/environment stable,
- (3) child stationary/environment changing, and
- (4) child and environment changing.

Scores as obtained on a 4-point scale: 0 (very well), 1 (just OK), 2 (almost), and 3 (not close). Cut-off scores below the 5th centile correspond to 'severe movement problems' while scores below the 15th centile represent a 'marked degree of movement difficulty'. Twelve behavioural traits that may influence motor performance, such as timid, overactive, passive, and fearful, are included in the behavior section. Scores in this section are obtained as 0 (rarely), 1 (occasionally), or 2 (often) (Wiat and Darrah, 2001).

2.15.2. Informal Assessment of DCD

2.15.2.1. The Children's Self Perception of Adequacy in and Predilection of Physical Activity scale (CSAPPA scale)

Recently, another test has been developed to evaluate children with suspect DCD. The Children's Self Perception of Adequacy in and Predilection of Physical Activity scale (CSAPPA) designed by Hay in 1992 (Hay, 1992), initially to assess children at risk for hypoactivity, has been found to be a reliable tool for assessing children at risk for DCD. It is a 20-item test designed to measure children's self perceptions of their adequacy in performing and their desire to participate in age-related physical activities. CSAPPA scale is a promising tool for identification of DCD children at an early stage as these children often go unrecognised by the school system (Hay et

al., 2004, Hay and Missiuna, 1998) and characterised by reduced age-related physical activities (Poulsen and Ziviani, 2004). However, CSAPPA has only been validated for English-speaking paediatric populations and further validation studies are necessary if it is to be used for non-English speaking children. Nevertheless, it should be noted that if the translation is accurate, then there are no convincing reasons why the CSAPPA should vary between different populations.

2.16. Comparisons of DCD Screening Instruments

Identifying DCD among children is a complex process. The selection of which screening test to use depends on a number of issues. These include the validity, reliability and practicality of each test and the purposes for its use in different settings.

Regarding the BOTMP, reliability of the subtests and composites was not adequately established by Bruininks in 1978. Bruininks, assessed two groups of second and six graders twice between 7 to 12 days and found that for most of the composites (except one) and half of the subtests interclass correlation was reported above 0.77 (Burton and Miller, 1998, p.166). Bruininks also examined the construct validity of the BOTMP with the following criteria: a) the relationship of the scores with chronological age, b) the factor structure of the 46 items, c) the score differences between children with or without impairments and d) the intercorrelations between test items (Burton and Miller, 1998, p.168). An interclass correlation of above 0.70 was obtained for both boys and girls in all subtests except balance. In the factor analysis of the 46 items of the long form five factors were identified with one factor (general motor development) accounting for almost 70% of the total factor variance. However, the other four factors (balance, bilateral coordination, strength, and upper limb-coordination) did not match with the respective items. This in turn, pointed out that the BOTMP may not be able to adequately distinguish performance between fine and gross motor tasks. The third criterion was better established since all children with mild to moderate and moderate to severe retardation, that Bruininks examined, demonstrated significantly lower scores compared to age-matched children without retardation. The fourth criterion also recognized that the motor abilities of the

children tested were differentiated with increasing age and indicated that fewer items may be used for younger children (Burton and Miller, 1998, p.168).

Sufficient evidence exists to support the use of the short form of the BOTMP. In the Bruininks experiments high composite correlations between the short and long form were reported (i.e 0.80, 0.93 and 0.90 across the ages of 4 to 12 years) (Burton and Miller, 1998, p.168).

Other studies have also evaluated the reliability and validity of the BOTMP-sf. Moore et al., (1986) assessed 32 children aged 5 years old with the BOTMP-sf. All children were assessed on two occasions, one week apart. These authors obtained a test–retest reliability correlation of 0.76. However, reliability of the item scores in the subtests was reported to be between 0 to 0.76. The correlation coefficient of 0 was reported on two occasions for one of the items in the bilateral coordination subtest. Across the four test sessions, intraclass correlation coefficient was reported at 0.87 with 13 of the children indicating consistent performance.

Nevertheless, the BOTMP has been validated for elementary school children and is the most commonly used standardised test to assess DCD in North America (Bruininks, 1978, Crawford et al., 2001). Similarly to many tests, the validity and reliability of the BOTMP test has been questioned in the past, however it still represents one of the most valid and reliable screening instruments for DCD.

M-ABC's reliability and validity have also received criticism. Reliability of the M-ABC was tested on 92 children from the United Kingdom falling in the first three age bands of the test. Reliability was defined as the two score falling on the same side of the 15th percentile. Of the 24 percentages calculated for the eight categories across the three age bands, 19 were 80% or above with a low of 66%. Percentages for the total impairment scores were 97% for 5 year olds, 91% for 7 year olds and 73 % of 9 year olds (Burton and Miller, 1998, p.174).

Few studies exist which address the validity of the M-ABC. Correlations between the total impairment score of the M-ABC and the BOTMP composite score have been found to be -0.53 for American children aged 4-12 years old

(Burton and Miller, 1998, p.175). Croce et al., (2001) tested the reliability and concurrent validity of the Movement ABC and concluded that the test is a valid measure for the identification of impairments in children aged 5-12 years old. However, Ruiz et al.,(2003) and Van Waelvelde et al., (2004) questioned the validity of the M-ABC across different age-bands and suggested that some items lack the required variance and were unable to substantially differentiate children. Furthermore, a recent study in Australia (Rodger et al., 2007) questioned whether the isolated use of the M-ABC (i.e qualitative aspects of movement), without further motor assessment would accurately identify all the children with DCD in a cohort of children who actually met the DSM-IV criteria for DCD. The authors also argue that while it is acknowledged that the M-ABC was designed for use in population based screening, it appears that in other settings (i.e clinical) its use to identify DCD is questioned. Nevertheless, its cross cultural validity has been supported by several studies and this has resulted in the M-ABC to be translated in several languages (Cools et al., 2008). Although the construct validity of the M-ABC has not been adequately established, it is considered a reliable and useful tool in identifying children with motor deficiencies.

Finally, several researchers have investigated whether both tests are able to identify the same children with DCD. In early 90's, Rikken et al., (1990) found that, contrary to the BOTMP, in all the cases where there was a disagreement concerning dysfunction-impairment, the TOMI (predecessor of the M-ABC) identified the child as displaying motor impairments. In another study addressing the assessment of children with clumsiness with the TOMI and the Test of Motor Proficiency it appeared that both tests identified the same number of children, which was 20 (5-5.6%), but each tool identified a different set of children (Mæland, 1992). Several others have reported moderate correlations ($r=-.53$) between the BOTMP and the M-ABC tests (Henderson and Sugden, 1992), while others (Wilson and McKenzie, 1998) who studied samples with reading difficulties, found similar results to Rikken et al., (1990).

2.17. Physical Fitness and DCD

Muscular strength, aerobic and anaerobic capacity, power, joint mobility-muscle flexibility, body composition and body balance, mainly constitute what we all understand as physical fitness. Without adequate physical fitness levels, most humans would be unable to properly work, study or participate in sports (Koutedakis and Sharp, 1999). Specifically, *physical fitness* is “a set of attributes that relates to the ability of the human to perform daily tasks with vigour and alertness, without undue fatigue and with ample energy to enjoy leisure-time pursuits and to meet unforeseen emergencies” (Caspersen et al., 1985). It is also considered to be a measure of many body functions (musculoskeletal, cardiorespiratory, metabolic and neurological) (Ortega et al., 2008). It is usually defined as: i) *Health related fitness*, which includes cardiorespiratory endurance, muscular endurance, strength, body composition and flexibility, and ii) *Skills related fitness*, which includes agility, balance, coordination, speed, power, reaction time (Caspersen et al., 1985, Lamb et al., 1988) (Figure 5).

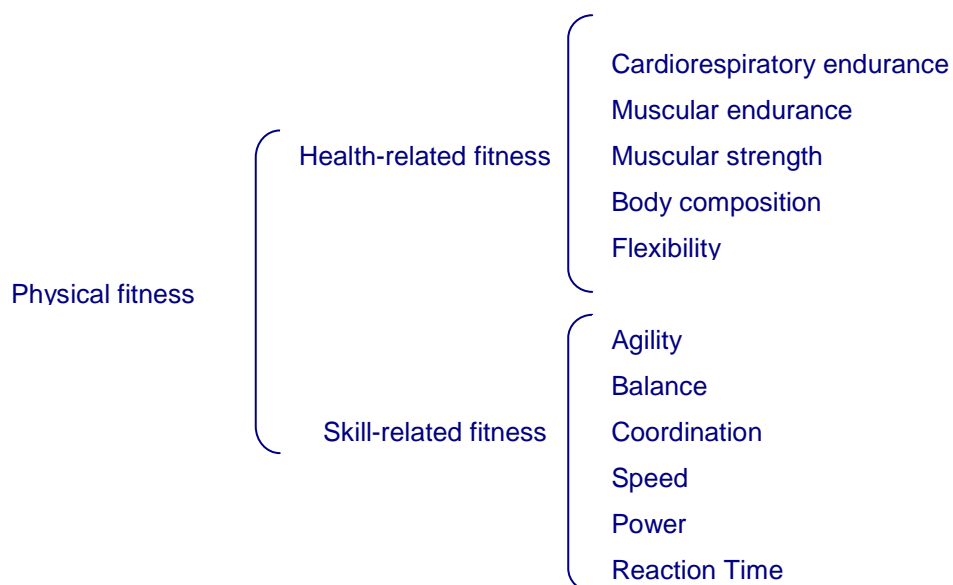


Figure 5. Components of physical fitness (Caspersen et al., 1985)
(Definitions of terms appear in APPENDIX 1)

Physical fitness is considered one of the most important health markers and a predictor of all cause morbidity and mortality (Ortega et al., 2008). The improvement of each component that constitutes physical fitness, particularly cardiorespiratory endurance, has been often equated with health improvements and disease prevention (Haskell et al., 1985). High fitness levels for adults have been associated to the prevention of cardiovascular disease, obesity, diabetes, bone diseases, high blood pressure, hypertension (Rowland, 2001). High physical fitness levels indicate highly active individuals, however the physical activity patterns of children are subject to a continuous change or decline during childhood (Boreham et al., 2001), and thus placing them at an increased risk for low physical fitness levels. It has been proposed that cardiorespiratory fitness is a stronger predictor of good health status compared to physical activity participation (Warburton et al., 2006). Recent evidence also suggests that the level of motor competence during childhood may predict adolescent fitness. Indeed, children with a high degree of control during specific non-locomotor tasks (i.e throwing, catching) may perform better at cardiorespiratory fitness tests compared to children with a lower degree of task control (Barnett et al., 2008).

Despite this, research on the relation between physical fitness and DCD has a relatively short life. In general, children diagnosed with the condition demonstrate reduced participation in age-related physical activities (Hay and Missiuna, 1998), which has been attributed to low self-confidence in social interactions (Hellgren et al., 1994).

Recent data suggest that children with DCD may also face a risk for being clinically obese and have low cardiorespiratory fitness levels (Flouris et al., 2003). As the prevalence estimates of motor impairment have been approximated internationally to vary from 1.8 to 10% (American Psychiatric Association, 1994, Henderson and Henderson, 2003, Lingam et al., 2009) this represents a significant proportion of the paediatric population likely to demonstrate a reduced level of age-related physical fitness leading possibly to an increased risk for obesity and low cardiorespiratory fitness at a later stage in life (Faught et al., 2005).

It is well established that increased fitness levels during childhood plays a significant role in the physical and psychological health of children (Boreham et al., 2004, Warburton et al., 2006). Also, the level of physical activity during this age may affect the risk of a number of diseases into adulthood, such as cardiovascular disease, osteoporosis and obesity (Hay, 1992). A recent study highlighted the health risks that children with DCD may face, resulting from non-participation in physical activities and it is now considered that this condition compromises physical activity levels (Hay et al., 2003). Hence, DCD may compromise physical fitness levels, excluding DCD children from any possible health related benefits emerging from participation in physical activities and non-sedentary lifestyles. Children with poor motor coordination tend to avoid physical activities and do not engage in physical education classes, due to voluntary withdrawal or exclusion from their peers (Hay and Missiuna, 1998). This is further related to their limited ability to perform adequately at specific motor tasks (Cairney et al., 2005, American Psychiatric Association, 1994). Furthermore, the level of activity is considered an important factor in the development of motor skills (Visser et al., 1998). Motor skills in turn, developed by engagement in physical activity, is a fundamental element of motor development (Reeves et al., 1999).

Published data highlighted the importance of including fitness assessments in groups of children with DCD (Hillier, 2007, Peters and Wright, 1999). This is related to the increased health risks these children may confront during childhood, adolescence and adulthood (Barnett et al., 2008). It has been stated that children with better motor proficiency may find it easier to follow an active lifestyle, compared to children with low motor proficiency that may choose a more sedentary lifestyle (Wrotniak et al., 2006).

Studies involving fitness assessments in groups of DCD children or children with learning difficulties have facilitated a better understanding of the relation between motor proficiency and fitness (Cairney et al., 2005, Cairney et al., 2005, Faught et al., 2005, Peters and Wright, 1999). However, most studies incorporate different methodologies and sample groups ranging from 6 to 14 year old children, making it hard to arrive at a universal agreement on the effects of DCD. Nevertheless, these studies (Cairney et al., 2007, Faught

et al., 2005, O'Beirne et al., 1994, Raynor, 2001, Reeves et al., 1999, Cairney et al., 2007) have surprisingly examined one or a combination of three to four physical fitness components in relation to DCD, thus preventing the configuration of a complete fitness profile in DCD children.

Reeves et al., (1999) examined the relationship between physical fitness and gross motor proficiency of fifty-one 5-to 6 year old kindergarten children. The authors reported that $\frac{1}{2}$ run mile performance was negative associated with measures of balance, bilateral coordination and strength. This was also the first set of data to indicate that increases in body weight may have a multidimensional effect on physical fitness, suggesting that body size parameters may account for variations in running activities.

Two years later Raynor (2001) highlighted the importance of strength and power in the everyday activities of children with DCD. The author identifies a significant mediating effect of DCD in the production of maximal force in these children. This finding is in line with previously published reports showing low levels of total anaerobic power output, relative peak power and absolute and relative mean power measured via the 30sec-Wingate test in children with DCD (O'Beirne et al., 1994).

Given that DCD children are reporting relatively low levels of participation in physical activities (Hay et al., 2003), it might be argued that these children may be at risk for becoming overweight or obesity. This has been recently confirmed at least in DCD boys participating in a cross sectional study (Cairney et al., 2005).

DCD children also tend to demonstrate compromised cardiorespiratory fitness levels. An association has been found between activity participation of DCD children and low levels of cardiorespiratory fitness (Cairney et al., 2007). Children with low motor proficiency were less likely to engage in substantial amounts of physical activity, which was finally associated with lower cardiorespiratory fitness scores (Cairney et al., 2007, Faught et al., 2005). As children with DCD are less confident with their physical abilities (i.e they may give up sooner during fitness tests), their lower scores in aerobic tests, compared to their normal peers, may be partially explained by variations in perceived adequacy (Cairney et al., 2006).

The first set of data to comprehensively examine the relation between physical fitness and motor proficiency is the study by Hands and Larkin (2006). These authors reported that for the majority of the fitness tests (e.g. sit and reach, multistage fitness test, and 50m sprint test, sit-ups and grip strength), children with motor learning difficulties displayed significantly lower scores compared to their typically developing peers, and they highlighted the importance of intervention programmes for the generally inactive DCD child.

Similarly, a significant mediating effect of DCD on the fitness performance of children aged 4-12 years has been found (Schott et al., 2007). Children with DCD, performed worse than their typically developing peers in aerobic endurance, anaerobic endurance and muscular strength when controlled for age, gender and body mass index. Conversely, children with good motor competence normally become fit adolescents (Barnett et al., 2008).

Longitudinal studies, involving children, in the areas of fitness and motor proficiency are rare and difficult to conduct. Only recently, Hands (2008) employed a 5-years longitudinal study as part of an assessment for fitness and motor skills in Australian children with low and high motor proficiency. Results revealed a fitness superiority of children with high motor proficiency over children with low motor proficiency. However, for certain fitness tests (sprint test and balance) there was a tendency of the low motor proficiency group to catch up to their normal developing peers with increasing age. For other fitness components (i.e cardiorespiratory fitness) greater differences between the two groups were obtained over time. These results suggest that for certain fitness components, which are mainly defined by engagement in physical activities, children with low motor competence are unlikely to produce optimal performance scores over time, because they simply tend to avoid engagement in activities.

In line with all aforementioned studies, Haga (2008) found significant differences in nine fitness tasks between children with movement difficulties and age-matched typically developing peers. In all the nine tasks and the total score of the Test of Physical Fitness, children with movement difficulties scored significantly worse compared to their normal peers. Again this study

revealed the increased risk of children with movement difficulties for compromised fitness levels and subsequent problems such as obesity and cardiovascular diseases at a later stage in life.

In a study by Cantell et al., (2008), children, adolescents and adults with low motor competence demonstrated generally lower fitness and health indices (i.e endurance, flexibility, and strength) compared to high motor competence groups. Interestingly, for the adult group, anthropometric assessments revealed that adults with low motor competence had a significantly higher body fat percentage in the trunk and lower bone mineral density [measured via Dual Energy X-ray Absorptiometry (DEXA)] compared to adults with high motor competence, suggesting that more active lifestyles may induce a positive impact in crucial risk factors for obesity and bone health.

In general, the association between motor proficiency and physical fitness do exist, but the appropriateness and methodologies of physical fitness testing in children with DCD is still a matter of further research.

2.18. Physical Fitness Intervention Programmes and DCD

Several studies have examined the effect of intervention programmes for the enhancement of motor skills for children with DCD. However, intervention methodologies may vary according to the fundamental theories underlining DCD (Hillier, 2007) and the theory that each research group implements which may be process oriented or task oriented or a combination of process and task oriented approaches (Sugden and Chambers, 2003). The increased DCD prevalence rates have facilitated the examination of possible treatment interventions. However, the efficacy of intervention programmes aiming at the development of gross and fine motor skills of DCD children remains controversial (Hillier, 2007). Sugden, (2007), suggests that a combination of cognitive, dynamic and ecological approaches of intervention may best suit the treatment needs of children with DCD. In particular, Sugden (2007) suggests that apart from the motor deficit that has to be somehow remediated, in order to observe subsequent benefits in everyday motor performance, children with DCD may also have to learn activities of daily living (i.e functional tasks) in order to properly function within the environment

that they spend most of their day (i.e school, home). As tends to happen with most children, children with DCD spend a great amount of time during school hours and extracurricular settings and in activities that promote fitness and other physical activity tasks. To date, however, limited information exists on the effectiveness of physical fitness interventions in paediatric populations with coordination difficulties.

The first attempt to introduce an intervention programme to a group of children with DCD was made by Peters and Wright (1999). The authors designed a 10-weeks interdisciplinary programme which included assessments of motor competence, perceived competence and physical fitness. Results revealed significant differences prior and post to intervention in the motor competence and forced vital capacity (FVC) of DCD children, and no changes in their perceived competence. However, this study recruited a small sample size ($n=14$) and did not include a control group.

Kaufman and Schilling (2007) implemented a 12 week task oriented strength training programme for a 5-year old boy with poor body awareness and DCD. These authors reported a positive change in the child in terms of increased muscle strength, general function and proprioception. Nevertheless, these results should be treated with caution due to the nature of the study (case report), however it highlights the importance of including strength training in children with DCD. Similarly, Fragala-Pinkham et al., (2005), after a 14-week group-based exercise intervention programme held twice per week followed by a 12-week home-based fitness intervention programme in nine children with physical and other developmental disorders, observed changes in energy expenditure, muscle strength and functional and gross motor abilities. The same authors also detected a greater impact of the group-based compared to the home-based intervention programme, suggesting that motivational factors during group exercise may induce greater fitness changes in contrast to exercising alone at home. However, these results should be carefully treated, in terms of generalization, as this study did not include a control group and the sample consisted of children with various developmental disorders, including DCD.

Despite the aforementioned information, growing evidence supports the notion that fitness interventions for children with DCD have been overlooked. Hillier (2007) reports that while the literature on DCD clearly demonstrates health, educational and physical activity participation problems there are still no appropriate intervention approaches to be offered. The author also argues that despite the different theoretical background behind intervention approaches, and as the mechanisms underlying DCD are still yet to be found, it is of great importance to utilize multidisciplinary intervention approaches, general indicators of activity participation and health levels of children with DCD in treatment designs.

2.19. Physical Activity of Children with DCD

Physical activity is defined as “any bodily movement that results in energy expenditure” (Caspersen et al., 1985). It is generally accepted that children with DCD tend to avoid participation in physical activities. While physical activity declines as normal children grow older (Strong, 1990), children with DCD seem to follow this pattern at an even greater rate. This may be related to the fact that DCD children may lack the fundamental skills responsible for the mastery of coordination during physical activities and may subsequently choose a more sedentary lifestyle in order to avoid inevitable comparisons with their normal peers (Fischer et al., 2005).

Published data demonstrate that improvement of motor competence is positively associated with physical activity and negatively associated with time spent during sedentary activities (Wrotniak et al., 2006). Selection of physical activity participation may be sex specific (Faught et al., 2008) or it may be explained by variations in perceived adequacy (Cairney et al., 2005, Cairney et al., 2005). It has been stated that there may be a threshold of motor competence above which children with DCD may demonstrate greater physical activity participation (Wrotniak et al., 2006).

Other issues involving participation in physical activity of children with DCD may be related to psychological constraints. Indeed, children with DCD report lower self confidence and perceptions of their physical abilities which may further lead to insufficient participation in physical activities compared to normally developing children (Hay, 1992, Hay and Missiuna, 1998).

Limited participation in physical activity has been identified as a mediating factor for cardiovascular disease (CVD), obesity, diabetes mellitus, elevated blood pressure, bone health and several other disease risk factors (Warburton et al., 2006). While limited information exists on the association between physical activity levels and high or low motor competence in paediatric populations, there is a need to better establish this relation mainly due to the fact that current DCD prevalence mirrors a significant amount of children who might be at risk for many of the aforementioned diseases.

Although positive associations between physical activity and health have been well documented (Bouziotas et al., 2004), the accurate measurement of physical activity patterns in children still require addressing as children demonstrate multidimensional and complex activity patterns (Livingstone et al., 2003). Practicality and high cost reasons have lead to the utilization of standardised self-administered questionnaires with questionable effectiveness, possibly due to the lack of comparisons with criterion reference standards of objectively measured physical activity (Sallis and Saelens, 2000). In children with DCD, one of the most frequent self-administered tests is the Participation Questionnaire (PQ) (Hay, 1992).

2.20. Physical Fitness, Physical Activity and Obesity of Greek Children

While Greek children are presenting significantly high percentages of overweight and obesity compared to their European peers (Lissau et al., 2004), few studies have examined associations between overweight, obesity, physical fitness and activity in school aged Greek children (Bouziotas et al., 2004, Christodoulos et al., 2006, Koutedakis and Bouziotas, 2003, Mamalakis et al., 2000, Manios et al., 2004, Tokmakidis et al., 2006). The World Health Organization (World Health Organization, 2006) defines overweight and obesity as abnormal or excessive fat accumulation that presents a risk to health. The widely used international cut-offs for overweight and obesity, offered by the International Obesity Taskforce (IOTF) and initially adopted from the study by Cole et al., (2000) are 25 kg/m² and 30 kg/m² respectively.

High levels of fitness and regular participation in physical activity in all children, adolescents and adults are related to the prevention of several diseases, namely: cardiovascular disease (CVD), obesity, diabetes mellitus,

hypertension and low density lipoprotein (Strong, 1990). While literature documents a number of benefits rising from engagement in physical activity, Greek children seem to be unable to catch up with published guidelines (Janssen, 2007) in regard to health and physical activity routines (Bouziotas et al., 2004).

Greek children exhibit high prevalence rates for overweight and obesity (as measured by the BMI) approximated totally at 22.7% for males and 18.3% for females in the age group of 7-12 years old. As age progresses it has been estimated that for the age group of 13-19 years old, Greek male children exhibit higher prevalence rates for overweight and obesity (totally: 29.6 %) compared to female children (16.1%) (Kapantais et al., 2004).

A follow-up study regarding Greek children revealed the high prevalence of obesity in Greek children compared to their American counterparts (Mamalakos et al., 2000). These results revealed that there was a tendency of obese children at age 6 to continue being obese at the age of 12, further suggesting that the grounds for the development of obesity at a later stage in life are set during early childhood.

A later study revealed high overweight and obesity rates for elementary Greek children at the age of eleven. Overweight rates were reported to be 35.6 % for the boys and 25.7 % for girls, and obesity rates were 6.7 % for both genders (Manios et al., 2004). The same authors also examined physical activity patterns and cardiorespiratory fitness in relation to rates of overweight and obesity. Apart from the observation that cardiorespiratory fitness is reflected by BMI scores in overweight and obese children, this study produced vague results in regard to objectively measured physical activity and its effect on overweight and obesity for Greek children.

Changes in obesity in relation to selected physical fitness components and physical activity over a year-period have been examined in Greek children from southern Greece (Christodoulos et al., 2006). Children who reported to participate for a significant amount of time in organised sports demonstrated significantly superior overall performance and had lower prevalence rates for overweight and obesity than children who were less active. Furthermore, obesity accounted for variations in organised physical

activity, cardiorespiratory fitness, explosive power and muscular endurance advocating that body size parameters explain a significant amount of variations in performance. Similar results were observed in elementary Greek children from the northern and southern parts of Greece (Tokmakidis et al., 2006) where overweight and obese children were overall inferior in most of the physical fitness tests undertaken (cardiorespiratory fitness, explosive power, agility, muscular endurance) apart from flexibility.

Greek physical education curriculum has been incriminated as insufficient to promote health related benefits in children (Koutedakis and Bouziotas, 2003). The Greek physical education curriculum allows for only two 45 minute physical education sessions per week for children aged 6 to 18 years. However, international guidelines for paediatric and adolescent populations are suggesting daily engagement in physical activities of at least 30 minutes and of moderate to vigorous intensity, in order to promote optimal health results (Janssen, 2007).

Nevertheless, Greek children are probably one of the least studied populations regarding motor, fitness and physical activity patterns.

CHAPTER 3: RATIONALE AND AIMS

DCD has been extensively studied by many research groups in different countries. However, limited data come from Southern European countries, and especially from Greece. Therefore, the aim of the present research work was to assess elements of DCD in Greek children in a series of four consecutive studies.

1. Prevalence of DCD worldwide ranges from 1.8 to 10% of all school-aged children (American Psychiatric Association, 1994, Lingam et al., 2009). DCD is a condition which may not only affect the functional capacity of the person diagnosed with it, but also imposes an impact on different aspects of life including health, academic, or emotional status (Hay and Missiuna, 1998). However, the prevalence of DCD in Greek children and the impact that this condition might have on health related parameters are not fully known. Therefore, one of the aims of the present work was to estimate DCD prevalence rates in Greek children and investigate whether they exhibit different obesity and cardiorespiratory fitness levels compared to an overseas sample.

2. Although motor performance characteristics in children with DCD are well documented (Haga, 2008), the physical fitness continuum and its impact on the health of these children has not been adequately addressed; previous research highlighting only selected parameters of fitness (Faught et al., 2005, Gueze, 2003). Since physical activity engagement enhances health related fitness (Boreham et al., 2004) it is not known whether children with DCD, who systematically avoid engagement in physical activities of any kind, demonstrate signs of compromised health. In normal children, avoidance of physical activity confines their ability for optimal performance, places a difficulty in the acquisition of new skills and exposes them to a great risk for overweight or obesity (D' Hodnt et al., 2009). Therefore, a second purpose of the current research work was to examine to the association between DCD and physical fitness levels.

3. Intervention strategies in children with DCD is of great importance as they may be proven beneficial in the control of severe signs and symptoms of the condition (Hillier, 2007). Nevertheless, given that DCD is a multidimensional disorder in nature, it is reasonable that researchers and professionals from different disciplines focus their work on different aspects of the condition. However, since a) there is no clear evidence as to which might be the best intervention strategy, and b) there is increasing evidence that a multidimensional intervention approach, incorporating exercise and activity participation might be useful for children with DCD (Hillier, 2007) part of the current work was to examine whether a motor skills and exercise training programme affects motor proficiency in a cohort of elementary school children with and without DCD.

4. Health related parameters and intervention strategies are highly interrelated (Strong et al., 2005). Improvement of one parameter may lead to the improvement of another, or an inverse relation may occur with detrimental effects for health (Ortega et al., 2008, Warburton et al., 2006). Physical activity participation is the means for improving body composition as well as physical fitness. It has been recently suggested that the level of participation in physical activity has been identified as a mediating factor for CVD in children with DCD. It is also known that children with DCD may stay unnoticed for many years as the signs and symptoms of this condition are not always obvious in educational settings, which makes early intervention strategies necessary in order for secondary health risks to decline (Missiuna et al., 2006). At the same time commonly used DCD screening tools such as the Bruininks Oseretsky Test of Motor Proficiency (BOTMP) or the Movement Assessment Battery (M-ABC) usually require considerable time to administer and are expensive. Recently, the Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) scale was introduced as a cost effective screening proxy of the short form of the BOTMP test (BOTMP-sf for use in children with DCD. Thus, the purpose of study 4 was threefold: (i) to test the hypothesis that DCD is linked with CVD risk, (ii) to identify the modes of physical activity that mediate the relationship between DCD and

CVD, and (iii) to evaluate the CSAPPA scale as a potential tool for screening Greek children for DCD.

CHAPTER 4: STUDIES

Study 1. Prevalence rates of DCD in Canada and Greece in relation to obesity and cardiorespiratory fitness.

(This Study has been published in the Journal of Adolescent Health: 39:125-127, 2006 - APPENDIX 2)

4.1.1. Introduction

Many school-aged children could be suffering from the syndrome that is so called “Developmental Coordination Disorder” (DCD) which describes children with a mild or severe difficulty to acquire new motor skills (American Psychiatric Association, 1994). A five-to-six percent from the school-aged population, with more boys than girls (Sugden and Chambers, 2003), has been found to be affected by DCD every year in Canada and USA (Kadesjo and Gillberg, 1998). This syndrome is known as a chronic disorder that also interferes with the child's daily living and academic achievements (Barnhart et al., 2003). Attempts to ascertain the etiology and physiological mechanisms and to also provide a confounding treatment, have met no success, rather than simple speculations (Barnhart et al., 2003). Some have stated that abnormalities or dysfunctions at the microscopic level of the nervous system (i.e. in the neurotransmitter or receptor systems) lead to this syndrome (Hadders-Algra, 2000).

It is widely accepted that this condition places the child in several secondary risks which might be emotional, social or health related in nature (Hay and Missiuna, 1998). However, many of these have not been adequately addressed in the literature. The role of physical activity and physical fitness, for example, in childhood and adulthood has been extensively investigated with surprisingly important outcomes for health, however no data were available for children with DCD until recently (Faught et al., 2005). It has been stated that more active children develop a healthier cardiovascular profile with this being carried over into adulthood (Boreham et al., 2001). Children with DCD are known to be overweight and have lower levels of physical fitness

than their normal school peers (O'Beirne et al., 1994), possibly due to voluntary withdrawal from physical activities. This, in turn, is related to the exclusion of those children from their peers in group play and other physical activities (Schoemaker and Kalverboer, 1994). In normal pediatric populations, excessive fatness affects the cardiorespiratory fitness and motor performance negatively (Boreham et al., 2001). Recent data have demonstrated that, at least for Canadian children, DCD is associated with reduced levels of physical activity, which may contribute to clinical obesity (CL_{OB}) and low cardiorespiratory fitness (L_{CF}) (Faught et al., 2005). Relative to children from other Western countries, such as Canada, Greek children lead a more inactive lifestyle (Katzmarzyk et al., 1999, Koutedakis and Bouziotas, 2003), exhibiting risk for CL_{OB} and L_{CF} (Bouziotas and Koutedakis, 2003). Therefore the purposes of this study were to: a) identify the prevalence of DCD in Greek school aged children, b) investigate whether children with DCD may be at risk for CL_{OB} and L_{CF}, and c) compare the data with available data from an overseas sample.

4.1.2. Methods

The current study was approved by the Greek local educational authorities, as well as by the Wolverhampton University Research Ethics Board.

4.1.2.1. Participants

A cross-sectional design was used with measurements conducted in five Greek elementary schools. Attention was given in the selection of schools to ensure that the participants represented socioeconomic, ethnic, and urban or rural group. A total of 329 students (Age: 11.3 ± 0.88 years; BMI: 19.60 ± 3.58) of a potential 577 children were screened, representing 16.7% of all 9-to-13 year old children living in the city of Trikala, Thessaly. Participation was voluntary (APPENDIX 3) and the sample represented a 67.9 % of all school children between the ages of 9-to-13 years old who attended those five schools. Details of anthropometric and demographic characteristics are presented in *Table 1*.

4.1.2.2. Procedures

All children underwent assessments for anthropometry, percent body fat, motor competence via the Bruininks –Oseretsky test of Motor Proficiency-*short form* (BOTMP-sf), activities of daily living by using the Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) Scale, participation in physical activities with a relevant questionnaire and cardiorespiratory fitness.

4.1.2.2.1. Anthropometry

Age (accurate to 1 month) was recorded. Weight was measured using an electronic scale (Tanita, TBF-521, Body Fat Monitor/Scale, Japan) to the nearest 0.1 kg.

4.1.2.2.2. Body fat percentage

Percent body fat was evaluated using Bioelectrical Impedance Analysis (BIA) with a portable hand-held body composition monitoring unit (RJL Systems, MI, USA). Participants were asked to lie supine while two electrodes were placed at the top part of the right hand and foot. To avoid dehydration (i.e. is considered a limitation of BIA), subjects were instructed to consume adequate amounts of water approximately 20 minutes prior to data collection, and to abstain from exercise eight hours before the assessment. Resistance and reactance factors were plotted by computer software (Cyprus Body Composition system 2.0) using previously established equations (Kotler et al., 1996) to estimate adiposity. Clinical obesity was considered at adiposity values >25% and >30% for boys and girls, respectively (Kotler et al., 1996).

4.1.2.2.3. The Bruininks-Oseretsky test of Motor Proficiency-Short Form (BOTMP-sf)

Using standardised procedures (Bruininks, 1978), this test was administered in a separate classroom or in the school's gymnasium behind a curtained barrier to ensure confidentiality. BOTMP-sf (APPENDIX 4) was used to assess criterion A "*Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by*

marked delays in achieving motor milestones (eg, walking, crawling, sitting), dropping things, 'clumsiness', poor performance in sports, or poor handwriting." of the DSM-IV (American Psychiatric Association, 1994). The BOTMP-sf is an individually administered test that assesses the gross and fine motor proficiency of children. The short form of the BOTMP was utilised for administrative and time-efficiency reasons. It was comprised of 14 items (Running speed and agility, Standing on preferred leg on balance beam, Walking forward heel-to-toe on balance beam, Tapping feet alternatively while making circles with fingers, Jumping up and clapping hands, Standing broad jump, Catching a tossed ball with both hands, Throwing a ball at a target with preferred hand, Response speed, Drawing a line through a straight path with preferred hand, Copying a circle with preferred hand, Copying overlapping pencils with preferred hand, Making dots in circles with preferred hand, Sorting shape cards with preferred hand), which examine general motor skills validated for elementary school-age children (Bruininks, 1978, Bruininks and Bruininks, 1977). The sub-tests include running speed and agility, balance, bilateral coordination, strength, upper-limb coordination and dexterity, and response speed. Low and high motoric efficiency was established based on standardised cut-offs. An age matched standard score of 37 was used to assign suspect DCD⁺ cases (Bruininks, 1978).

4.1.2.2.4. Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) Scale

The CSAPPA scale, designed initially to assess children at risk for hypoactivity (Hay, 1992), has been found to be a reliable tool for assessing children at risk for DCD (Hay et al., 2004). It is a 20-items test designed to measure children's self perceptions of their adequacy in performing and their desire to participate in age-related physical activities. For this purpose the scale was used to address criterion B of the DSM-IV "*The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.*". This questionnaire is presented with 3 imbedded factors in terms of scoring: i) Adequacy, ii) Predilection and iii) Enjoyment of physical education class. Overall, CSAPPA measures generalized self-efficacy toward physical activities (Hay and Missiuna, 1998, Hay et al., 2004). The Greek

version of CSAPPA was created as a comprehensive translation of the original English version and both can be found in APPENDIX 5.

4.1.2.2.5. Physical Activity Participation Questionnaire (PQ)

Physical activity participation was measured via the Participation Questionnaire (PQ- APPENDIX 6) (Hay, 1992). This is a 61-item self administered questionnaire that assesses children's participation levels in free-time play, seasonal recreational activities, school sports, community based team sports and clubs, and private sports dances and lessons which requires approximately 20 minutes to complete. Participation in organised activities includes a 1-year period, and free play is considered from typical activity choices. Subtotal calculations are available for free play, organised play and inactivity. Total participation in activity is estimated as the sum of organised and free play activities. This test has been proven to be a reliable tool for accessing physical activity in elementary school children and has produced a test-retest reliability of 0.81 (Hay, 1992). In line with other self administered physical activity questionnaires, the PQ has demonstrated moderate criterion validity (0.62) (Hay, 1992, Hay and Donnelly, 1996), and has been used in the past to access physical activity engagement in DCD⁺ children (Cairney et al., 2005). In the Greek version of the PQ, certain winter activities that the North American children are likely to engage in were replaced by activities equivalent in energy cost which are popular in the specific settings of Greece (McArdle et al., 2003).

4.1.2.2.6. Cardiorespiratory Fitness

This test requires running back and forth between two lines set 20m apart in synchrony with a sound signal emitted from an audio compact disc according to published procedures (Leger and Lambert, 1982). Subjects performed the test in groups of 15 to instigate motivation and were verbally motivated by the investigators to reach volitional exhaustion. The test was individually terminated when each volunteer was unable to maintain the prescribed pace (i.e., ± 1 sec) for three consecutive signals. Cardiorespiratory fitness levels were evaluated using maximal oxygen uptake ($\dot{V}O_{2\max}$) predicted from the equation: $\dot{V}O_{2\max} = (MAS \times 6.65 - 35.8) \times 0.95 + 0.182$ where MAS is the

maximal attained speed ($\text{km}\cdot\text{h}^{-1}$) achieved during the test (Flouris et al., 2005). The demarcation point for low cardiorespiratory fitness was set at 40 and 35 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for boys and girls, respectively, according to available guidelines (Shvartz and Reibold, 1990).

4.1.3. Statistical analysis

Analysis of variance (ANOVA) was used to determine gender specific differences for each continuous parameter. Chi-square tests were conducted for prevalence rates comparisons, and accompanying confidence intervals were calculated for identified DCD (DCD^+), CL_{OB} , and L_{CF} . Independent samples T-Test was used to determine differences in the activities of daily living and physical activity participation between DCD^+ and DCD^- . The level of significance was set at $p \leq 0.05$.

4.1.4. Results

Table 1 depicts anthropometric, body fat, CF, and BOTMP-*sf* data derived from the present sample as well as comparable data from a Canadian study [data used with permission from Faught et al., (2005) *Journal of Adolescent Health*]. Significant gender and sample-specific differences were detected in most parameters. Particularly, boys exhibited significantly lower scores in % body fat and greater scores in $\dot{\text{V}}\text{O}_{2\text{max}}$ and BOTMP-*sf* compared to girls. Also, Greek children demonstrated significantly higher body fatness and lower CF and BOTMP-*sf* scores than their Canadian peers.

Table 1. Sample characteristics of anthropometry, physical fitness and motoric competence (mean [SD]).

	Canadian ^a	Greek
Number of Participants		
Entire Sample	591	329
Males	322	175
Females	269	154
Age (years)		
Entire Sample	11.7 (10.2-13.2)	11.3 (10.4-12.2) ^b
Males	11.7 (10.2-13.2)	11.3 (10.4-12.2) ^b
Females	11.7 (10.2-13.2)	11.3 (10.4-12.2) ^b
Mass (kg)		
Entire Sample	45.5 (32.3-58.7)	43.0 (33.1-52.9) ^b
Males	45.8 (32.2- 59.4)	43.9 (33.2-54.6)
Females	45.2 (33.5-56.9)	42.1 (33.3-50.9) ^b
Body Fat (%)		
Entire Sample	16.1 (5.8-26.4)	22.9 (15.2-30.6) ^b
Males	11.4 (3.2-19.6)	22.6 (14.4-30.8) ^{b,c}
Females	21.9 (12.4-31.4)	23.3 (16.3-30.3) ^c
Fat Free Mass (kg)		
Entire Sample	37.5 (28.4-46.6)	32.8 (26.9-38.7) ^b
Males	39.9 (30.0-49.8)	33.4 (27.0-39.8) ^{b,c}
Females	34.4 (27.6-41.2)	32.1 (26.7-37.5) ^{b,c}
$\dot{V}O_{2max}$ (ml·kg ⁻¹ ·min ⁻¹)		
Entire Sample	37.3 (29.7-44.9)	35.6 (29.8-41.4) ^b
Males	38.9 (31.0-46.8)	37.6 (31.4-43.8) ^c
Females	35.3 (28.6-42.0)	33.5 (29.2-37.8) ^{b,c}
BOTMP- <i>sf</i> (Standard Score)		
Entire Sample	55.3 (42.5-68.1)	49.6 (37.0-62.2) ^b
Males	58.1 (46.7-69.5)	51.9 (38.7-65.1) ^{b,c}
Females	52.3 (38.7- 65.9)	46.9 (35.4-58.4) ^{b,c}

^a Data from Faught et al., *Journal of Adolescent Health* (2005) (with permission).

^b significantly different between countries ($p < 0.05$).

^c significantly different between genders of the same country ($p < 0.05$).

Table 2 shows prevalence rates (% [\pm 95% confidence interval (CI)]) for Canadian and Greek children with (+DCD) and without (-DCD) Developmental Coordination Disorder in relation to CL_{OB} and L_{CF}. Specifically, a 19% of Greek children were screened as DCD⁺ compared with

the previously reported 8% of their Canadian peers (Faught et al., 2005). Similarly, DCD⁺ Greek children demonstrated greater prevalence rates for CL_{OB} and L_{CF} compared with the Canadian sample (48% vs. 23% and 90% vs. 83%, respectively). Greater prevalence rates for CL_{OB} and L_{CF} were also detected in the DCD⁻ Greek children compared with their Canadian peers (25% vs. 12% and 65% vs. 55%, respectively). Significant differences were observed in the prevalence rate comparisons for CL_{OB} and L_{CF} between children with (+DCD) and without (-DCD) Developmental Coordination Disorder.

Table 2. Prevalence rates [% (\pm 95% CI)] for clinical obesity (CL_{OB}) and low cardiorespiratory fitness (L_{CF}) in Canadian and Greek Children with (DCD⁺) and without DCD (DCD⁻).

		DCD	CL _{OB}	L _{CF}
Canadian (n=591)	DCD⁺	8 (6-10) ^a	23 (22-24) ^{a,b}	83 (77-89) ^{a,b}
	DCD⁻	92 (90-94) ^a	12 (9-15) ^{a,b}	55 (52-58) ^{a,b}
Greek (n=329)	DCD⁺	19 (15-23) ^a	48 (47-49) ^{a,b}	90 (86-94) ^{a,b}
	DCD⁻	81 (76-86) ^a	25 (20-30) ^{a,b}	65 (62-68) ^{a,b}

^a Significantly different between countries ($p < 0.05$).

^b Significantly different between DCD⁺ and DCD⁻ ($p < 0.05$).

Tables 3 and 4 demonstrate mean scores of the Greek sample from the CSAPPA scale and the PQ questionnaire. Results revealed that significant ($p < 0.05$) differences were observed between DCD⁺ and DCD⁻ children in CSAPPA Adequacy, and only for boys with and without DCD in the CSAPPA Predilection and CSAPPA Total components. In regard to the PQ significant differences were observed between DCD⁺ and DCD⁻ girls in the organised activity component, and between DCD⁺ and DCD⁻ boys in the inactivity component. Significant differences were also detected between DCD⁺ and DCD⁻ for the entire sample in the inactivity component.

Table 3. Mean differences (mean \pm SD) in the CSAPPA components between DCD⁺ and DCD⁻.

		DCD ⁺	DCD ⁻
CSAPPA _{Adequacy}	Boys	21.1 \pm 3.9	23.7 \pm 3.3*
	Girls	19.9 \pm 4.3	21.8 \pm 4.0*
	Entire Sample	20.4 \pm 4.2	22.9 \pm 3.6*
CSAPPA _{Predilection}	Boys	27.8 \pm 4.3	30.7 \pm 3.7*
	Girls	26.9 \pm 4.9	27.9 \pm 5.0
	Entire Sample	27.3 \pm 4.6	29.4 \pm 4.6*
CSAPPA _{EnjPhEdu}	Boys	10.9 \pm 1.4	11.3 \pm 1.1
	Girls	10.5 \pm 2.0	10.7 \pm 1.8
	Entire Sample	10.7 \pm 1.8	11.1 \pm 1.5
CSAPPA _{Total}	Boys	60.0 \pm 8.2	65.7 \pm 6.0*
	Girls	57.3 \pm 8.7	60.6 \pm 8.8
	Entire Sample	58.4 \pm 8.6	63.4 \pm 7.8*

* Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻.

Table 4. Mean differences (mean \pm SD) in the PQ components between DCD⁺ and DCD⁻.

		DCD ⁺	DCD ⁻
Organised Activity	Boys	5.4 \pm 4.1	7.2 \pm 5.0
	Girls	5.5 \pm 4.5	3.8 \pm 3.9*
	Entire Sample	5.5 \pm 4.8	5.7 \pm 4.8
Free Time Play	Boys	17.2 \pm 4.1	17.5 \pm 3.3
	Girls	14.9 \pm 3.7	15.4 \pm 3.5
	Entire Sample	15.8 \pm 4.0	16.6 \pm 3.6
Inactivity	Boys	4.3 \pm 3.4	2.8 \pm 1.9*
	Girls	3.8 \pm 1.6	3.3 \pm 2.2
	Entire Sample	4.0 \pm 2.4	3.0 \pm 2.1*
Total Activity	Boys	22.6 \pm 7.0	24.7 \pm 6.4
	Girls	20.5 \pm 6.8	19.2 \pm 5.7
	Entire Sample	21.3 \pm 6.93	22.3 \pm 6.7

* Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻.

4.1.5. Discussion

The purposes of this study were to: a) identify the prevalence of DCD in Greek school aged children, b) investigate whether children with DCD may be at risk for CL_{OB} and L_{CF}), and c) compare the data with available data from an overseas sample. The results revealed that Greek children exceeded expected DCD prevalence rates for pediatric populations (American Psychiatric Association, 1994). The major finding of this study is the high prevalence of DCD in Greek children, reaching 19%. In recent literature, current prevalence rates in several European, American and Canadian regions, independently of the diagnostic tools have been found to be between 6 and 10% of all school-aged children (American Psychiatric Association, 1994, Henderson and Henderson, 2002, Kadesjo and Gillberg, 1999). This difference in the DCD prevalence rates may not necessarily symbolize a failure of the Greek children to acquire age-appropriate motor skills. It may rather be a failure of the BOTMP-*sf* test to accurately discriminate between children who are truly identified as DCD cases and those who are simply inactive. Therefore it would be reasonable to interpret our cases of DCD as “suspect” because we did not use a clinical assessment that addressed all the criteria of the DSM-IV. However, in the absence of a “gold standard” test for diagnosing DCD (Henderson and Barnett, 1998) the BOTMP-*sf* serves as a reasonable choice, as it is widely used to detect motor coordination problems in children (Visser, 2003). Despite its extensive use in North America, the BOTMP-*sf* has never been previously employed in Greek children, highlighting the need for customized cut-off points for this population.

The high prevalence rates for DCD observed herein are also reflected in the responses to the CSAPPA scale, which for the purposes of this study was used as a means of assessing Criterion B of the DSM-IV. Not surprisingly both boys and girls with DCD⁺ had significantly lower scores in CSAPPA Adequacy, while boys also had significantly lower scores in CSAPPA Predilection component. The CSAPPA Adequacy component reflects the confidence of the child to participate in activities that his or her normal peers are involved in. The CSAPPA Predilection component mirrors the childrens' preference for a particular activity (Hay, 1992). The results observed herein clearly reflect

confidence and predilection difficulties for children with DCD⁺. Similar results have been observed in the past for children with DCD⁺ where it was found that lower confidence-efficacy scores in the CSAPPA scale explained why children with DCD⁺ participate less in activities compared to their normal peers (Cairney et al., 2005).

Significant differences were also detected between DCD⁺ and DCD⁻ for the entire sample in the inactivity component of the PQ. The results also revealed that girls with DCD⁺ report significantly greater participation in physical activities (i.e organised activities), compared to girls without DCD⁻. This finding may reflect the great variability which is usually observed in the signs and symptoms of children with DCD⁺ and may further suggest that the present girls sample may have had less activity engagement problems compared to other problems of academic achievement for example. However, this should be treated as speculation since academic achievement was not assessed in this study. Boys with DCD⁺ on the other hand reported greater inactivity rates compared to their normal peers. This finding is in consistence with previous published data which suggest that children with DCD⁺ are less likely to be physically active (Cairney et al., 2005).

In addition, contrary to the past and present literature, quite interesting was the finding that more girls than boys were diagnosed as having DCD. This could be related to the massive screening with the BOTMP-*sf*, whereas previous studies utilized smaller sample sizes and different instruments.

Furthermore, Greek children with and without DCD demonstrated greater prevalence rates for CL_{OB} and L_{CF} compared to the overseas sample. (Faught et al., 2005). This could be attributed to the Greek school's physical education curriculum which represents only a 6% of the total curriculum (Koutedakis and Bouziotas, 2003) as opposed to 10% in Canada. Reports suggest that, due to the reduction of physical education classes in two hours per week in the Greek curriculum since 1989, Greek schools do not achieve the required levels of motor and cardiovascular fitness standards (Koutedakis and Bouziotas, 2003). Also, available data advocate that Greek children are relatively inactive compared with their peers from other countries (Katzmarzyk et al., 1999, Koutedakis and Bouziotas, 2003). This may have accounted for

the significant CL_{OB} and L_{CF} differences found herein between Greek and Canadian children (Faught et al., 2005). Nevertheless, limited physical activity may result in a decline in selected fitness-related parameters and deterioration in motor skills acquisition (Koutedakis and Bouziotas, 2003). Hence, it is unlikely that relatively inactive children may acquire the necessary skills to adequately perform specific motor tasks. It could be, therefore, that existing lifestyle differences between Greek and Canadian children are echoed in the great DCD prevalence rates observed herein. Even though the vast majority of the literature addressing the problem of overweight and obesity among Greek children supports the present high prevalence rates of obesity, it is logical to assume that the estimation of obesity may have been influenced by the current evaluation method. Bioelectrical impedance analyses can only be used to predict body composition. A subsequent problem of this approach is that it involves two predictions: raw measurements are used to predict a body component or property using regression equations while this value is then converted to final body composition data using further assumptions. The problem lies in the fact that such equations may not be valid in populations other than those from which they were derived (Wells and Fewtrell, 2006). It could be therefore, that the use of BMI might have provided an overestimation of obesity.

Within this study's limitations, it is concluded that Greek children exhibit greater prevalence rates for DCD, CL_{OB} , L_{CF} compared to overseas pediatric populations. Increasing levels of physical activity may assist in reducing such prevalence rates in children.

Study 2. Physical fitness and Developmental Coordination Disorder in Greek children

(This Study has been published in the Pediatric Exercise Science 21:186-195, 2009 – APPENDIX 7)

4.2.1. Introduction

Developmental coordination disorder (DCD), describes children with a difficulty to execute age related motor activities (American Psychiatric Association, 1994). While the aetiology and prognosis for DCD are still unclear, various motor symptoms may appear in children with the disorder (DCD⁺) compared to those without (DCD⁻) (Visser, 2003). In general, DCD is now affecting 5 to 19% of school aged children in America and Europe (American Psychiatric Association, 1994, Henderson and Henderson, 2002, Tsiotra et al., 2006).

DCD has been linked to paediatric conditions such as obesity and risk for cardiovascular diseases during adulthood (Faught et al., 2005), and it may secondarily lead to emotional and cognitive disturbances (Miller et al., 2001). DCD⁺ children appear to demonstrate motor difficulties in their daily living that compromise their activity levels and, therefore, physical fitness and health (Hay et al., 2004). Indeed, DCD⁺ children report lower physical activity levels, perhaps due to voluntary withdrawal or exclusion from their peers (Hay and Missiuna, 1998), while they are overweight, obese and demonstrate lower aerobic power levels (Tsiotra et al., 2006) than normal children.

The main components of physical fitness include body composition, flexibility, strength, speed and cardiorespiratory fitness (Deforche et al., 2003, Warburton et al., 2006). Adequate physical fitness in children and adolescents provides short and long term health benefits (Sallis et al., 2000). These include psychological (Biddle et al., 2004) and bone (Shi et al., 2006) health, optimal body composition (Koutedakis and Bouziotas, 2003), and may limit the risk of developing cardiovascular diseases and obesity during adulthood (Boreham et al., 2001, Rowland, 2001).

Several published reports suggest that Greek children in general have low levels of aerobic power (Bouziotas and Koutedakis, 2003) high

prevalence of obesity and low physical activity levels (Bouziotas et al., 2004). The Greek life style (Koutedakis et al., 2005), and even the existing school curriculum (Koutedakis and Bouziotas, 2003) have been put forward as possible explanations for these observations. However, unlike other parts of the World where fitness performance has been extensively studied in relation to motor difficulties (Cairney et al., 2005, Hands and Larkin, 2006, Raynor, 2001, Reeves et al., 1999), only limited data (Tsiotra et al., 2006) are available on the associations between selected fitness parameters and DCD in Mediterranean paediatric populations, including those from Greece. In view of the dearth of such data, the present study was conducted to investigate the extent to which Greek children with DCD⁺ respond differently in a series of physical fitness tests compared to their peers.

4.2.2. Methods

This study is a cross-sectional analysis of the effects of a variety of physical fitness determinants on DCD. The original baseline survey, which provides the basis for the current investigation has been published elsewhere (Tsiotra et al., 2006).

4.2.2.1. Participants

The sample studied consisted of 177 Greek children, 97 boys (Age: 11.83 ± 0.97 years; BMI: 20.75 ± 3.57) and 80 girls, (Age: 12.21 ± 0.58 years; BMI: 20.05 ± 3.27) who reported benign past medical histories. This sample represented approximately 23% of all 10-12-year old schoolchildren who were living in the typical middle-class Greek town of Trikala, and derived from six different elementary schools. The study was approved by the University's of Wolverhampton Research Ethics Committee and the Greek local educational authorities. Written informed consent (APPENDIX 3) was obtained from participants and their parents after full explanation of data collection procedures.

4.2.2.2. Procedures

Children who consented to participate in this study were assessed for anthropometry, physical fitness and motor proficiency. Participants were free of any known medical condition and reported to participate in regular PE classes at school. Physical fitness assessments consisted of 6 individual tests for body composition (BMI), flexibility (SR), leg explosive power (VJ), hand strength (HS), speed (40m ST), and cardiorespiratory fitness (CF). Motor proficiency was evaluated using the short form of the Bruininks-Oseretsky Test of Motor Proficiency-Short Form (BOTMP-*sf*). Engagement in activities of daily living was recorded using the Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) Scale and physical activity participation was obtained with the Participation Questionnaire (PQ).

4.2.2.3. *Physical Fitness Assessment*

Volunteers were subjected to six different tests which were carefully selected to provide data on key physical fitness parameters as previously suggested (Deforche et al., 2003, Warburton et al., 2006). These tests were as follows:

4.2.2.3.1. Anthropometry and body composition

Age (accurate to 1 month) was recorded. Weight was measured using an electronic scale (Tanita, TBF-521, Body Fat Monitor/Scale, Japan) to the nearest 0.1 kg.

Weight was measured to the nearest 0.1 kg using an electronic scale (TANITA, TBF-521, Japan). Height was measured with a standardised stadiometer to the nearest, 0.1cm (SECA-GYMNA, Germany). BMI was calculated as $\text{weight} \cdot \text{height}^{-2}$ ($\text{kg} \cdot \text{m}^{-2}$).

4.2.2.3.2. Flexibility

The sit and reach test (Wells and Dillon, 1952) was used to assess flexibility of the vertebrae and posterior leg muscles. Children were instructed to sit on the floor, resting their bare feet vertically against a box of 30 cm height and had to lean forward with straight arms and knees and reach over the top surface of the box. The distance between toes and finger was measured. Positive values were recorded if the participant was able to reach further than

his/her toes, while negative values were recorded if the participant was unable to touch the toes. Three trials were given to all children and the best score in centimetres was recorded.

4.2.2.3.3. Leg Explosive Power

This test requires the participant to jump from a 90° knee squatting position with the hands next to the hips and a jump meter with digital display adjusted to the waist (T.K.K. 5106 JUMP MD; Takei Scientific Instruments, Tokyo, Japan). Score was recorded as the jump height in centimetres.

4.2.2.3.4. Hand Strength

Participants were instructed to squeeze a calibrated hand dynamometer (T.K.K. 5101, TAKEI, JAPAN) as forcefully as possible, to assess the static strengths of both dominant and non-dominant hands. The handle length was adjusted to control for variations in hand size. The best of two maximal efforts by each hand was recorded. Hand strength was calculated as the mean of both hands.

4.2.2.3.5. Speed

Each participant started the test started from a standing position with the preferred foot at the starting line. The timer stood at the finish line, called ready and signalled the start of the speed test. Time was recorded to the nearest 0.1 seconds and speed in m.s^{-1} .

4.2.2.3.6. Cardiorespiratory Fitness

This test requires running back and forth between two lines set 20m apart in synchrony with a sound signal emitted from an audio compact disc according to published procedures (Leger and Lambert, 1982). Subjects performed the test in groups of 15 to instigate motivation and were verbally motivated by the investigators to reach volitional exhaustion. The test was individually terminated when each volunteer was unable to maintain the prescribed pace (i.e. $\pm 1\text{sec}$) for three consecutive signals. Cardiorespiratory fitness levels were evaluated using maximal oxygen uptake ($\dot{V}\text{O}_{2\text{max}}$) predicted from the equation: $\dot{V}\text{O}_{2\text{max}} = (\text{MAS} \times 6.65 - 35.8) \times 0.95 + 0.182$ where MAS is the maximal

attained speed ($\text{km}\cdot\text{h}^{-1}$) achieved during the test (Flouris et al., 2005). The demarcation point for low cardiorespiratory fitness was set at 40 and 35 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ for boys and girls, respectively, according to available guidelines (Shvartz and Reibold, 1990).

4.2.2.4. *The Bruininks-Oseretsky test of Motor Proficiency-Short Form (BOTMP-sf)*

Using standardised procedures (Bruininks, 1978), this test was administered in a separate classroom or in the school's gymnasium behind a curtained barrier to ensure confidentiality. BOTMP-sf (APPENDIX 4) was used to assess criterion A *“Performance in daily activities that require motor coordination is substantially below that expected given the person’s chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (eg, walking, crawling, and sitting), dropping things, “clumsiness,” poor performance in sports, or poor handwriting.”* of the DSM-IV (American Psychiatric Association, 1994). This test is an individually administered test that assesses the gross and fine motor proficiency of children. The short form of the BOTMP was utilised for administrative and time-efficiency reasons. It was comprised of 14 items (Running speed and agility, Standing on preferred leg on balance beam, Walking forward heel-to-toe on balance beam, Tapping feet alternatively while making circles with fingers, Jumping up and clapping hands, Standing broad jump, Catching a tossed ball with both hands, Throwing a ball at a target with preferred hand, Response speed, Drawing a line through a straight path with preferred hand, Copying a circle with preferred hand, Copying overlapping pencils with preferred hand, Making dots in circles with preferred hand, Sorting shape cards with preferred hand), which examine general motor skills validated for elementary school-age children (Bruininks, 1978, Bruininks and Bruininks, 1977). The sub-tests include running speed and agility, balance, bilateral coordination, strength, upper-limb coordination and dexterity, and response speed. Low and high motoric efficiency was established based on standardised cut-offs. An age matched standard score of 37 was used to assign suspect DCD⁺ cases (Bruininks, 1978).

4.2.2.5. Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) Scale

The CSAPPA scale, designed initially to assess children at risk for hypoactivity (Hay, 1992), has been found to be a reliable tool for assessing children at risk for DCD (Hay et al., 2004). It is a 20-items test designed to measure children's self perceptions of their adequacy in performing and their desire to participate in age-related physical activities. For this purpose the scale was used to address criterion B of the DSM-IV "*The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.*" the activities of daily living of all the children. This questionnaire is presented with 3 imbedded factors in terms of scoring: i) Adequacy, ii) Predilection and iii) Enjoyment of physical education class. Overall, CSAPPA measures generalized self-efficacy toward physical activities (Hay and Missiuna, 1998, Hay et al., 2004). The Greek version of CSAPPA was created as a comprehensive translation of the original English version and both can be found in APPENDIX 5.

4.2.2.6. Physical Activity Participation Questionnaire (PQ)

Physical activity participation was measured via the Participation Questionnaire (PQ-APPENDIX 6) (Hay, 1992). This is a 61-item self administered questionnaire that assesses children's participation levels in free-time play, seasonal recreational activities, school sports, community based team sports and clubs, and private sports dances and lessons which requires approximately 20 minutes to complete. Participation in organised activities includes a 1-year period, and free play is considered from typical activity choices. Subtotal calculations are available for free play, organised play and inactivity. Total participation in activity is estimated as the sum of organised and free play activities. This test has been proven to be a reliable tool for accessing physical activity in elementary school children and has produced a test-retest reliability of 0.81 (Hay, 1992). In line with other self administered physical activity questionnaires, the PQ has demonstrated moderate criterion validity (0.62) (Hay, 1992, Hay and Donnelly, 1996) and has been used in the past to access physical activity engagement in DCD⁺

children (Cairney et al., 2005). In the Greek version of the PQ, certain winter activities that the North American children are likely to engage in were replaced by activities equivalent in energy cost which are popular in the specific settings of Greece (McArdle et al., 2003).

4.2.3. Statistical Analyses

Two-way (gender x DCD⁺) ANCOVAs were used to test for differences in the variables of interest, with age set as a covariate. Independent samples T-Test was used to assess for differences in the activities of daily living and physical activity participation between DCD⁺ and DCD⁻ children. Statistical significance was set at $p < 0.05$.

4.2.4. Results

The use of the BOTMP-sf test indicated that 12 [Boys: $n=6$ (6.2%); Girls: $n=6$ (7.5%)] out of 177 volunteers could be classified as suspect DCD⁺ and the remaining 165 as DCD⁻. Comparisons between the two groups revealed that although DCD⁺ children demonstrated lower values in all six physical fitness parameters compared to DCD⁻ group, only four of them (i.e., BMI, VJ, HS and 40m ST) were found to be significantly different.

Because of the relatively small size of the DCD⁺ group, the effect size index (mean difference/pooled standard deviation) was calculated for all studied parameters. It was found that the effect size for the different parameters ranged from 0.13 to 1.47 which is regarded as acceptable (Cohen, 1977) (*Table 5*).

Table 5. DCD ⁺ Effect sizes for all physical performance parameters						
	BMI	SR	VJ	HS	40m ST	CF
Effect Size	0.87	0.35	1.13	0.13	1.47	0.41

Two-way (gender x DCD⁺) ANCOVAs were calculated to test for differences in the studied variables, with age as covariate. The analysis revealed a main motor proficiency (i.e., DCD group) effect for BMI, [$F_{(1, 177)} = 8.68$, $p < 0.05$, $\eta^2 = 0.05$], VJ [$F_{(1, 177)} = 14.17$, $p < 0.05$, $\eta^2 = 0.08$] and 40m ST [$F_{(1, 173)} = 24.26$, $p < 0.05$, $\eta^2 = 0.13$]. No significant differences were found for

SR [$F_{(1, 177)} = 1.82, p > 0.05, \eta^2 = 0.01$], HS [$F_{(1, 177)} = 2.46, p > 0.05, \eta^2 = .06$] and CF [$F_{(1, 170)} = 1.23, p > 0.05, \eta^2 = 0.01$]. However, in the case of HS it is well known that HS increases proportionally with body size, i.e., both height and weight (Nevill and Holder, 2000). By adopting a similar model structure to that used by Nevill and Holder (2000), the proposed model for the hand grip strength (HS) of the present Greek children is given as follows:

$$HS = a \cdot \text{height}^{k_1} \cdot \text{mass}^{k_2} \cdot \exp(b \cdot \text{age}). \quad (1)$$

The model (Eq. 1) can be linearised with a log-transformation. A linear regression analysis on $\log(HS)$, can then be used to estimate the unknown parameters of the log transformed model (Eq. 2).

$$\log(HS) = \log(a) + k_1 \cdot \log(\text{height}) + k_2 \cdot \log(\text{mass}) + b \cdot \text{age} \quad (2)$$

When we analysed log-transformed hand grip strength using log-transformed body mass and height, as well as age as covariates, significant differences in HS were found [$F_{(1, 177)} = 10.6, p < 0.001, \eta^2 = 0.06$] with DCD⁺ children having lower adjusted HS=15.55 (kg) compared with DCD⁻ children, HS=18.08 (kg). Examination of the means showed that DCD⁺ children had greater BMI, lower VJ scores and higher values of speed than DCD⁻ children. The analysis also revealed a main gender effect for CF [$F_{(1, 170)} = 9.15, p < 0.05, \eta^2 = 0.05$]. Examination of the means revealed that boys had higher pAP mean values than girls. No gender effects were identified for BMI [$F_{(1, 177)} = 0.62, p > 0.05, \eta^2 = 0.00$], SR [$F_{(1, 177)} = 1.18, p > 0.05, \eta^2 = 0.01$], VJ [$F_{(1, 177)} = 0.51, p > 0.05, \eta^2 = 0.00$], HS [$F_{(1, 177)} = 0.01, p > 0.05, \eta^2 = 0.00$], 40m ST [$F_{(1, 173)} = 2.87, p > 0.05, \eta^2 = 0.02$] (*Table 6*). Also, no interaction effects ($p > 0.05$) were identified for any of the studied variables.

Table 6. Physical fitness parameters in relation to condition and gender (mean \pm sd)

		DCD ⁺	DCD ⁻
BMI	Boys	23.51 \pm 4.37	20.56 \pm 3.46
	Girls	22.84 \pm 3.51	19.82 \pm 3.16
	Total	23.17 \pm 3.79 *	20.53 \pm 3.34
SR (cm)	Boys	12.33 \pm 7.42	12.84 \pm 5.88
	Girls	12.50 \pm 10.13	17.12 \pm 6.41
	Total	12.42 \pm 8.47	14.76 \pm 6.47
VJ (cm)	Boys	23.83 \pm 4.79	31.18 \pm 5.25
	Girls	24.67 \pm 2.42	28.25 \pm 4.77
	Total	24.25 \pm 3.65 *	30.00 \pm 5.20
HS (kg)	Boys	15.89 \pm 3.04	18.50 \pm 3.80
	Girls	17.26 \pm 3.29	18.34 \pm 3.91
	Total	16.57 \pm 3.10	18.43 \pm 3.84
40m ST (sec)	Boys	8.51 \pm 0.75	7.61 \pm 0.63
	Girls	8.95 \pm 0.61	7.94 \pm 0.65
	Total	8.73 \pm 0.7 *	7.76 \pm 0.66
CF (ml·kg ⁻¹ ·min ⁻¹)	Boys	39.17 \pm 11.74 †	39.06 \pm 6.37
	Girls	30.49 \pm 1.34	34.43 \pm 4.79
	Total	34.44 \pm 8.75	37.06 \pm 6.17

* values significantly different ($p < 0.05$) between DCD⁺ and DCD⁻ groups

† values significantly different ($p < 0.05$) between genders of the DCD⁺ group

Tables 7 and 8 depict responses of the sample to the CSAPPA scale and the physical activity PQ. Results revealed that significant ($p < 0.05$) differences were observed between girls with DCD⁺ and without DCD⁻ in CSAPPA Predilection and CSAPPA Total components. Significant differences ($p < 0.05$) were observed between DCD⁺ and DCD⁻ girls in the free time play component.

Table 7. Mean differences (mean \pm SD) in the CSAPPA components between DCD⁺ and DCD⁻.

		DCD ⁺	DCD ⁻
CSAPPA _{Adequacy}	Boys	23.3 \pm 2.8	24.3 \pm 3.3
	Girls	19.5 \pm 4.8	21.3 \pm 3.7
	Entire Sample	21.4 \pm 4.3	23.0 \pm 3.8
CSAPPA _{Predilection}	Boys	32.3 \pm 4.9	32.2 \pm 3.9
	Girls	24.2 \pm 6.3	29.4 \pm 5.0*
	Entire Sample	28.2 \pm 6.8	31.0 \pm 4.7
CSAPPA _{EnjPhEdu}	Boys	11.6 \pm 0.5	11.6 \pm 0.9
	Girls	9.2 \pm 2.4	11.3 \pm 1.1
	Entire Sample	10.4 \pm 2.1	11.4 \pm 1.0
CSAPPA _{Total}	Boys	67.3 \pm 6.6	68.2 \pm 6.2
	Girls	52.8 \pm 11.6	62.1 \pm 8.1*
	Entire Sample	60.1 \pm 11.8	65.4 \pm 7.8

* Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻.

Table 8. Mean differences (mean \pm SD) in the PQ components between DCD⁺ and DCD⁻.

		DCD ⁺	DCD ⁻
Organised Activity	Boys	5.5 \pm 3.2	5.1 \pm 3.9
	Girls	3.5 \pm 2.2	3.1 \pm 3.0
	Entire Sample	4.5 \pm 2.8	4.2 \pm 3.6
Free Time Play	Boys	19.0 \pm 3.4	18.2 \pm 3.3
	Girls	13.6 \pm 2.1	16.4 \pm 3.2*
	Entire Sample	16.3 \pm 3.9	17.4 \pm 3.4
Inactivity	Boys	3.1 \pm 1.9	3.3 \pm 1.9
	Girls	5.5 \pm 2.3	4.2 \pm 2.0
	Entire Sample	4.3 \pm 2.4	3.7 \pm 2.1
Total Activity	Boys	26.0 \pm 1.7	23.2 \pm 5.7
	Girls	17.1 \pm 2.7	19.5 \pm 5.2
	Entire Sample	20.1 \pm 5.0	21.3 \pm 5.7

* Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻.

4.2.5. Discussion

The purpose of this study was to investigate the extent to which 12-years old children with high or low motor proficiency (or DCD level), respond differently in a series of physical fitness tests. It was found that DCD⁺ children demonstrated higher BMI, and lower VJ, 40m ST and HS than those classified as DCD⁻. A similar but non-significant trend was also found for the remaining studied parameters, i.e., SR, and CF. Unlike previous reports where only a couple of fitness (Cairney et al., 2007, Faught et al., 2005, Raynor, 2001) and gross motor skill (Cantell et al., 2008, Hands and Larkin, 2006) parameters were studied in relation to DCD at a time, the current data is an attempt to establish better associations between DCD and physical fitness. Furthermore, our study constitutes the first serious attempt in this area involving children from a Mediterranean country.

The present findings are in line with a recent report on a Greek paediatric population which confirmed that DCD⁺ children, both boys and girls, appear to have higher BMI values than their normal peers (Tsiotra et al., 2006). As BMI increases by adopting more sedentary lifestyles (Koutedakis et al., 2005), the higher values for BMI reported herein may be partly attributed to the tendency by DCD⁺ children for minimal engagement in general physical activities, school physical education and organised plays (Cairney et al., 2005, Hay and Missiuna, 1998). Therefore, any imbalance between energy consumed and energy expended may lead to BMI increases and possibly to obesity and compromised health (Jago and Baranowski, 2004). However, BMI increases and the inevitable accumulation of body fat directly affects the performance of body-mass-dependent activities (Ara et al., 2004), such as VJ, HS and 40m ST, which is in line with the lower scores revealed by our DCD⁺ children compared to those treated as DCD⁻.

In regard to the HS test, a significant difference between DCD⁺ and DCD⁻ groups was obtained when logarithmic transformed HS was incorporated as the response variable and log-transformed body mass and height were adopted as covariates. The results suggest that the HS scores increase with mass and height, and once these components are accounting for, lower scores in the HS test were obtained for the DCD⁺ compared to the DCD⁻ group, i.e., because the

DCD⁺ group were heavier, the HS scores were already lower but when these were adjusted for body size, the HS scores of the DCD⁺ children were significantly lower than DCD⁻ children. Interestingly, the mass and height exponents were 0.25 and 2.01 respectively, suggesting, in line with previously published data, that HS scores increase in proportion to body size at a rate a little greater than the cross-sectional area of body size (Nevill and Holder, 2000).

Comparisons between DCD⁺ and DCD⁻ children revealed no differences in the SR test although a trend was noted in favour of the DCD⁻ group. To the best of our knowledge there are no data available which relate DCD with flexibility for this specific age group. However, as flexibility is a factor commonly developed by engagement in physical activity, the results found herein may be attributed to the fact that Greek children in general demonstrate reduced participation in physical activities (Koutedakis and Bouziotas, 2003) which makes differences between DCD⁺ and DCD⁻ children difficult to detect. Indeed, results from the CSAPPA scale support the present finding. In all the CSAPPA components except CSAPPA_{Predilection} and CSAPPA_{Total} for girls there were no significant differences between children with DCD⁺ and without DCD⁻. The finding is also supported by evidence suggesting that both children with (DCD⁺) and without (DCD⁻) DCD demonstrated extremely low scores in the PQ. Previous research has reported three times as much physical activity engagement of children (i.e., 60.6) with DCD⁺ from other countries (Faught et al., 2005) compared to Greek children. The present findings may also be credited to the minor neuromuscular coordination that this type of activity requires, which in turn makes difficult to detect any substantial differences between DCD⁺ and DCD⁻ children. Furthermore, the present findings may be attributable to the fact that children with low motor competence have heterogeneous fitness profiles and, thus, extreme ranges of flexibility or inflexibility can be observed (Cantell et al., 2008).

Our findings are in line with published data advocating the superiority of boys over girls in the CF test for this age group (Olds et al., 2006). However, there were no significant differences between DCD⁺ and DCD⁻

children. Previous research has shown that DCD⁺ boys are at greater risk for low cardiorespiratory fitness compared to girls (Cairney et al., 2007), however this may be a result of a general DCD screening bias in favouritism of the boys (Hay and Donnelly, 1996). Indeed, girls with DCD⁺ have been shown to demonstrate reduced self-competence and lowered feelings of perceived physical self-efficacy (Poulsen and Ziviani, 2004). These results may be partially explained by the fact that Greek children generally demonstrate lower cardiorespiratory fitness scores compared to children from other countries (Bouziotas et al., 2001), thus making statistically difficult to separate DCD⁺ and DCD⁻ children. In fact, DCD⁻ children reported lower cardiorespiratory fitness values below the international standards for optimum health (Shvartz and Reibold, 1990). The lack of differences between DCD⁺ and DCD⁻ children in aerobic power levels may also partly be explained by the existing school physical education curriculum in Greece, which involves only two forty-five minutes sessions per week for elementary school children. According to published data, such school physical education curriculum cannot support the improvement of motor and physical abilities in children (Koutedakis and Bouziotas, 2003) and may account for the fact that our DCD⁺ and DCD⁻ reported similar scores of cardiorespiratory fitness.

It is reasonable to assume that the present results may have been influenced by a number of limitations. It is the very nature of the current work where always DCD⁺ children are expected to perform considerably less well in tasks than their normal counterparts. In taking this point further, it may be the actual perception of the DCD⁺ children about physical activities that may have influenced the current results. It has been reported that ~34 % of the differences found in the running performance of DCD⁺ children compared to DCD⁻ can be explained by perceived adequacy (Cairney et al., 2006). Considering the relatively small volunteer sample (23%) and the large population differences (Snedecor and Cochran, 1989), the present results should be cautiously interpreted. In addition, considering the small sample of the suspected DCD⁺ cases in this study, the aforementioned gender differences should be treated with prudence.

Although the BOTMP-*sf* has been used before to identify DCD cases, it has to be highlighted that this method yields “probable” or “suspect” cases. The diagnostic criteria for DCD should involve not only establishing poor motor coordination, but also associations between coordination difficulties and impairments to social and academic functioning. There are other assessments of motor coordination difficulties in children (i.e., Movement ABC) (Henderson and Sugden, 1992), which, unlike the BOTMP, are measures of impairment not proficiency per se. Finally, there is no gold standard for diagnosing DCD and we should be cautious in assuming the children in this study all have the disorder.

Within the limitations of the present study, it is concluded that Greek DCD⁺ children tend to perform worse in selected physical fitness components compared to their normal peers. Future studies should focus on the assessment of larger samples of DCD⁺ children in different countries including Greece to identify the prevalence of compromised physical fitness in these children and provide sufficient intervention strategies through school physical education and extra-curriculum activities. IQ measures should also be included in future studies, so that children with low IQ (≤ 70) are either excluded, or their intellectual abilities are considered when comparison to typically developing peers. Finally, the effects of motor incompetence on the child’s daily life as well as selected co-morbidity elements should be addressed in the future.

Study 3. Exercise training intervention for children with DCD

(This study is under review)

4.3.1 Introduction

Children with Developmental Coordination Disorder (DCD) are characterised by impaired motor skills acquisition and executive functioning (American Psychiatric Association, 1994) and represent between 5% (US, Northern Europe) (American Psychiatric Association, 1994, Henderson and Henderson, 2002) and 19 % (South Europe) (Tsiotra et al., 2006) of all schoolchildren. While DCD is not a life-threatening condition, these children often remain unnoticed by the school system (Willoughby and Polatajko, 1995) and develop a compromised health profile (Faught et al., 2005) and severe academic and social problems (Missiuna et al., 2006).

The increased DCD prevalence rates have given rise to research exploring for possible treatment interventions. Alas, the efficacy of intervention programmes aiming at the development of gross and fine motor skills of DCD children remains limited and controversial (Hillier, 2007). In this light, previous research has shown that appropriate exercise training can induce health- and skill-related outcomes which may include cardiorespiratory and muscular endurance, strength, body composition, flexibility, balance, coordination and speed (Caspersen et al., 1985).

Children of all ages often practice simple and more complex bodily activities which may lead to the progressive development of motor skills and functional tasks. Activities incorporated in such training may also lead to acquisition of fine motor skills that involve eye-hand coordination (Sullivan et al., 2008). Therefore, motor skills and exercise training is a logical candidate for improving motor competence of children with DCD. Indeed, a recent review suggested that multipurpose exercise training programmes incorporating health- and skill-related parameters may contribute to the development of motor competence in children with DCD in a better fashion compared to traditionally accepted interventions (Hillier, 2007). Yet, the possibility of improving motor competence of children with DCD through motor skills and exercise training has received very limited attention. To date, there have been only two published studies examining the efficacy of interventions

based on specific components of fitness for improving motor proficiency in children with DCD (Fragala-Pinkham et al., 2005, Kaufman and Schilling, 2007). However, these studies incorporated very small sample sizes (1-2 children) and methodologic issues that constrain interpretation of the findings. Therefore, the purpose of the present study was to examine whether a motor skills and exercise training programme affects motor proficiency in a cohort of elementary school children with and without DCD.

4.3.2. Methods

4.3.2.1. Participants

The study was approved by the University's Research Ethics Committee and the Greek local educational authorities. In order to identify a group of children with DCD large enough to satisfy the purposes of the present study, students aged 10-12 years from four randomly-chosen elementary schools in the city of Patra (southern Greece) were invited to a motor proficiency screening using the short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-sf). Children also completed the Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) Scale and a participation in physical activity questionnaire (PQ). From the 178 students screened, 20 were classified as DCD positive (+DCD) and were matched with 48 DCD negative (-DCD) peers. The total of 68 children (Age: 10.79 ± 3.66 years; BMI: 20.46 ± 3.42) were free of any known pathological conditions and participated regularly in physical education (PE) classes.

4.3.2.2. Procedures

After obtaining written informed consent from all participants and their parents (APPENDIX 8), the sample was randomly assigned into two intervention [+DCD_I ($n=10$) and -DCD_I ($n=22$)] and two control groups [+DCD_C ($n=10$), -DCD_C ($n=26$)]. Thereafter, the main part of the study initiated incorporating an 8-week exercise training intervention programme as well as data collection assessments conducted before (T1) and after (T2) the intervention. In each assessment, all children underwent testing for DCD, activities of daily living and physical activity participation, body composition and physical fitness from

the same well-trained personnel and at approximately the same time of the day.

4.3.2.2.1. Motor skills and Exercise Training Programme

The National PE curriculum for elementary schools incorporates two 45-minute sessions per week. In the present study, the two control groups (i.e., $^{+}DCD_C$ and $^{-}DCD_C$) followed the normal PE curriculum conducted by the school's PE instructors. In contrast, the two intervention groups (i.e., $^{+}DCD_I$ and $^{-}DCD_I$) underwent an 8-week school-based motor skills and exercise training programme which involved three 45-minute sessions per week taking place during PE and Flexible Zone classes (i.e music, painting). The motor skills and exercise training programme was conducted by well-trained PE instructors and was comprised by the components described in *Table 9*.

Table 9. Components of the motor skills and exercise programme.

Time	Skill	Task	Exercise	Task
Weeks 1-4	Spatial Awareness	Group drills (e.g., movement to specific directions upon trainer's call, moving with eyes closed)	Aerobic power	Continuous run, circuit training, aerobic games
	Posture	Group games (taking specific stances upon trainer's call)	Flexibility	Energetic & passive flexibility drills
	Balance	Walking on balance beam, moving between plastic sticks or hoops	Strength	Hopping in one or both legs
	Coordination	Games & circuits for ball handling, hopping on one leg while making opposite hand moves	Speed	Speed circuits, 20m-30m-40m dashes
	Movement Accuracy	Games & drills with walking or running & throwing at targets while in stance	Neuromuscular joining Agility	Skipping, combination of skipping and running drills Running-picking object games
Repetitions: 10 / Sets: 3 / Set recovery: 1 minute Weeks 1-2. Intensity: 40-50% of theoretical maximum / Weeks 3-4. Intensity: 50-60% of theoretical maximum A 45-minute typical session consisted of 10 minutes warm-up, 30 minutes basic training, 5 minutes recovery				
Weeks 5-8	Spatial Awareness	Group drills (e.g., movement to specific directions upon trainer's call, moving in different directions with eyes closed)	Aerobic Power	Continuous run, circuit training, aerobic games
	Posture	Group games (taking specific stances upon trainer's call from different starting positions)	Muscular strength & endurance	Medicine ball drill, weight bearing exercise
	Balance	Walking on balance beam, moving between plastic sticks or hoops	Flexibility	Energetic & passive flexibility drills
	Coordination	Games and circuits for ball handling, hopping on legs while making opposite hand moves	Speed	Speed circuits, 20m-30m-40m dashes
	Movement accuracy Reaction Speed	Games and drills for throwing at targets while in stance, hopping, running Running, hopping, throwing balls upon optical and verbal trainer's call		
Repetitions: 10 / Sets: 3 / Set recovery: 1 minute Weeks 5-6. Intensity: 60-70% of theoretical maximum / Weeks 7-8. Intensity: 70-75% of theoretical maximum A 45-minute typical session consisted of 5 minutes warm-up, 35 minutes basic training, 5 minutes recovery				

4.3.2.2.2. Bruininks-Oseretsky Test of Motor Proficiency-short form (BOTMP-sf)

DCD was assessed by the standardised BOTMP-sf (Bruininks, 1978). This test was administered by well-trained researchers, in a separate classroom or in the school's gymnasium behind a curtained barrier to ensure confidentiality. BOTMP-sf (APPENDIX 4) was used to assess criterion A *“Performance in daily activities that require motor coordination is substantially below that expected given the person’s chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (eg, walking, crawling, and sitting), dropping things, “clumsiness,” poor performance in sports, or poor handwriting.”* of the DSM-IV (American Psychiatric Association, 1994). The BOTMP-sf is an individually-administered test that assesses the gross and fine motor proficiency of children. The short form of the BOTMP was utilised for administrative and time-efficiency reasons. It is comprised of 14 items, which examine the general motor skills and has been validated for elementary school-age children (Bruininks, 1978, Bruininks and Bruininks, 1977). The sub-tests include running speed and agility, balance, bilateral coordination, strength, upper-limb coordination and dexterity, and response speed. Low and high motor coordination was established based on standardised cut-offs. An age matched BOTMP-sf score ≤ 37 was used to classify suspect ⁺DCD cases (Bruininks, 1978).

4.3.2.2.3. Children’s Self Perception of Adequacy in and Predilection for physical Activity (CSAPPA) Scale

The CSAPPA scale, designed initially to assess children at risk for hypoactivity (Hay, 1992), has been found to be a reliable tool for assessing children at risk for DCD (Hay et al., 2004). It is a 20-items test designed to measure children’s self perceptions of their adequacy in performing and their desire to participate in age-related physical activities. For this purpose the scale was used to address criterion B of the DSM-IV *“The disturbance in criterion A significantly interferes with academic achievement or activities of daily living.”* This questionnaire is presented with 3 imbedded factors in terms of scoring: i) Adequacy, ii) Predilection and iii) Enjoyment of physical education class. Overall, CSAPPA measures generalized self-efficacy toward physical activities (Hay and Missiuna,

1998, Hay et al., 2004). The Greek version of CSAPPA was created as a comprehensive translation of the original English version and both can be found in APPENDIX 5.

4.3.2.2.4. Physical Activity Participation Questionnaire (PQ)

Physical activity participation was measured via the Participation Questionnaire (PQ-APPENDIX 6) (Hay, 1992). This is a 61-item self administered questionnaire that assesses children's participation levels in free-time play, seasonal recreational activities, school sports, community based team sports and clubs, and private sports dances and lessons which requires approximately 20 minutes to complete. Participation in organised activities includes a 1-year period, and free play is considered from typical activity choices. Subtotal calculations are available for free play, organised play and inactivity. Total participation in activity is estimated as the sum of organised and free play activities. This test has been proven to be a reliable tool for accessing physical activity in elementary school children and has produced a test-retest reliability of 0.81 (Hay, 1992). In line with other self administered physical activity questionnaires, the PQ has demonstrated moderate criterion validity (0.62) (Hay, 1992, Hay and Donnelly, 1996) and has been used in the past to access physical activity engagement in DCD⁺ children (Cairney et al., 2005). In the Greek version of the PQ, certain winter activities that the North American children are likely to engage in were replaced by activities equivalent in energy cost which are popular in the specific settings of Greece (McArdle et al., 2003).

4.3.2.2.5. Body Composition

Body mass was measured to the nearest 0.1 kg using an electronic scale (TANITA, TBF-521, Japan). Height was measured to the nearest, 0.1 cm using a standardised stadiometer (SECA-GYMNA, Germany). Body mass index (BMI) was calculated as $\text{weight} \cdot \text{height}^{-2}$ ($\text{kg} \cdot \text{m}^{-2}$).

4.3.2.2.6. Physical Fitness Assessment

Volunteers underwent 5 different tests which were selected to provide data on key physical fitness parameters as previously suggested (Caspersen et al., 1985). These tests were as follows:

4.3.2.2.6.1. Flexibility

The Sit and Reach test (Wells and Dillon, 1952) was used to assess flexibility of the spine and posterior leg muscles. Children were asked to sit on the gymnasium floor, resting their bare feet vertically against a box of 30 cm height. To perform the test, children had to lean forward with straight arms and knees and reach over the top surface of the box. The distance between toes and finger was measured. Positive values were recorded if the participant was able to reach further than his/her toes. Negative values were recorded if the participant was unable to touch the toes. Three trials were given to all volunteers and the best score in centimetres was recorded.

4.3.2.2.6.2. Hand Strength

The children's static strengths of both dominant and non-dominant hands were assessed via squeezing a calibrated hand dynamometer (T.K.K. 5101, Takei Scientific Instruments, Tokyo, Japan) as forcefully as possible. The handle length was adjusted to control for variations in hand size. The best of two maximal efforts by each hand was recorded. Mean hand strength was calculated as the sum of each hand's best trial divided by two $[(\text{right} + \text{left})/2]$.

4.3.2.2.6.3. Leg explosive power

A standard vertical jump was used to assess the leg explosive power. This test requires the participant to jump from a 90° knee squatting position with the hands to the hips and with a jump meter with digital display adjusted to the waist (T.K.K. 5106 Jump MD; Takei Scientific Instruments, Tokyo, Japan). The score was recorded as the jump height in centimetres.

4.3.2.2.6.4. Speed

The 40m sprint test started from a standing position with the preferred foot at the starting line. The timer stood at the finish line, called ready and signalled the start of the speed test. Time was recorded to the nearest 0.01 seconds. Running speed was calculated as distance·time⁻¹ (m·sec⁻¹).

4.3.2.2.6.5. Cardiorespiratory Fitness

Participants performed the test in groups of five and were instructed to run back and forth between two fixed lines 20 meters apart. The groups had to follow a recorded signal emitted from an audiocassette player. The frequency of the signal increased by 0.5 km·h⁻¹ each minute from a starting speed of 8.5 km·h⁻¹. Several shuttle runs make up each stage of the test and pupils are instructed to keep pace with the signals for as long as possible. The test was terminated when each participant could not follow the prescribed pace for three consecutive signals. The maximal speed attained was then used to calculate cardiorespiratory fitness in ml·kg⁻¹·min⁻¹ (Flouris et al., 2005).

4.3.3. Statistical Analysis

A factorial 2 x 4 [i.e., two times (T1 and T2) x four groups (+DCD_I, -DCD_I, +DCD_C, and -DCD_C)] multivariate analysis of variance (MANOVA), followed by post-hoc t-tests for time and group incorporating Bonferonni adjustments, was used to detect the effect of intervention on motor competence. Significance level was set at $p < 0.05$ except for post-hoc tests in which a Bonferroni adjustment was applied.

4.3.4. Results

Results revealed a significant main effect of time [$F_{(14, 115)} = 3.795$, $p < 0.01$; $\eta^2 = 0.316$] on the BOTMP-*sf* score ($p < 0.01$) suggesting that motor competence changed from T1 to T2. Significant main effects of group [$F_{(42, 351)} = 4.098$, $p < 0.01$; $\eta^2 = 0.329$] were observed for BMI ($p = 0.00$), BOTMP-*sf* score ($p < 0.01$), cardiorespiratory fitness ($p < 0.01$), hand strength ($p = 0.03$), leg explosive power ($p = 0.02$), speed ($p < 0.01$), and free time play activities ($p = 0.03$), showing that the values of these variables were different across the four groups. Finally, although no significant ($p > 0.05$) interaction (time*group) was observed, it is worth mentioning that the time*group interaction for BOTMP-*sf* score was relatively

close to the significance level ($p=0.087$). This suggests that changes from T1 to T2 in motor competence were more prevalent in specific groups.

Results for time- and group-specific post hoc analyses are illustrated in *Table 10*. Time-specific (i.e., T1 vs. T2) comparisons revealed a significant increase in BOTMP-*sf* score for $^{+}DCD_I$ and $^{-}DCD_I$ children ($p=0.01$ and $p=0.05$, respectively) and a significant decrease in speed for $^{-}DCD_I$ children ($p=0.01$). Group-specific comparisons revealed that while $^{+}DCD_I$ children at T1 showed a lower BOTMP-*sf* score than $^{-}DCD_I$ and $^{-}DCD_C$ ($p<0.01$ and $p<0.01$, respectively) at T2 these differences did not exist ($p>0.05$). In a similar fashion, while $^{+}DCD_I$ children at T1 showed lower speed values than $^{-}DCD_I$ and $^{-}DCD_C$ ($p=0.03$ and $p=0.01$ respectively) at T2 these differences were extinct ($p>0.05$). Further group-specific differences for both times were found for BMI, aerobic fitness and leg explosive power ($p<0.05$). On the other hand, results for the PQ and CSAPPA indices did not show any time- or group-specific differences ($p>0.05$) (*Tables 11 and 12*).

Table 10. Mean values (mean \pm SD) for fitness in Time 1 and Time 2 for all groups.			
		Time 1	Time 2
BMI (kg/m^2)	DCD^{+}	22.82 ± 2.93^b	23.38 ± 3.23^b
	$DCD^{+}_{\text{Controls}}$	22.50 ± 4.20^d	22.86 ± 4.09^d
	DCD^{-}	$19.02 \pm 2.70^{b,d}$	$19.25 \pm 2.67^{b,d}$
	$DCD^{-}_{\text{Controls}}$	20.00 ± 3.16	20.50 ± 3.10
BOTMP- <i>sf</i>	DCD^{+}	$52.5 \pm 9.0^{*,b,c}$	$63.7 \pm 9.1^{*}$
	$DCD^{+}_{\text{Controls}}$	$55.2 \pm 8.2^{d,e}$	$60.6 \pm 10.6^{d,e}$
	DCD^{-}	$66.6 \pm 5.9^{*,b,d}$	$69.9 \pm 4.6^{*,d}$
	$DCD^{-}_{\text{Controls}}$	$66.6 \pm 4.9^{c,e}$	69.2 ± 5.2^e
Cardiorespiratory Fitness ($\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$)	DCD^{+}	31.60 ± 3.90^c	34.56 ± 4.16^c
	$DCD^{+}_{\text{Controls}}$	34.23 ± 6.22	35.88 ± 5.77
	DCD^{-}	36.09 ± 6.45	37.73 ± 5.71
	$DCD^{-}_{\text{Controls}}$	39.32 ± 5.80^c	40.08 ± 5.59^c
Flexibility (cm)	DCD^{+}	15.2 ± 8.1	17.5 ± 8.1

	DCD ⁺ Controls	14.3 ± 6.3	15.1 ± 4.9
	DCD ⁻	15.2 ± 6.0	15.5 ± 6.4
	DCD ⁻ Controls	17.4 ± 9.1	17.8 ± 9.0
Leg Explosive Power (cm)	DCD ⁺	25.5 ± 5.5 ^c	25.4 ± 5.2 ^c
	DCD ⁺ Controls	28.0 ± 6.5	27.2 ± 6.9
	DCD ⁻	28.2 ± 4.8	28.5 ± 3.9
	DCD ⁻ Controls	30.6 ± 4.4 ^c	30.3 ± 4.8 ^c
Hand Strength (kg)	DCD ⁺	26.5 ± 6.2	27.5 ± 6.5
	DCD ⁺ Controls	19.7 ± 8.6	22.4 ± 8.5
	DCD ⁻	25.5 ± 5.8	26.3 ± 5.8
	DCD ⁻ Controls	23.0 ± 7.6	25.7 ± 6.4
Speed (m·h ⁻¹)	DCD ⁺	4.67 ± 0.53 ^{b, c}	4.66 ± 0.48 ^c
	DCD ⁺ Controls	4.65 ± 0.52 ^{d, e}	4.68 ± 0.53 ^e
	DCD ⁻	5.14 ± 0.34 ^{a, b, d}	4.70 ± 0.36 ^{a, f}
	DCD ⁻ Controls	5.29 ± 0.40 ^{c, e}	5.16 ± 0.39 ^{c, e, f}

* Significant differences ($p < 0.05$) between times for the same group.

a Significant differences ($p < 0.05$) between DCD⁺ and DCD⁺ controls for the same time.

b Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻ for the same time

c Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻ controls for the same time

d Significant differences ($p < 0.05$) between DCD⁺ controls and DCD⁻ for the same time

e Significant differences ($p < 0.05$) between DCD⁺ controls and DCD⁻ controls for the same time

f Significant differences ($p < 0.05$) between DCD⁻ and DCD⁻ controls for the same time

Table 11. Mean scores (mean ±SD) for PQ components in Time 1 and Time 2 for all groups.

		Time 1	Time 2
Organised Activity	DCD ⁺	5.4 ± 4.5	4.3 ± 3.9
	DCD ⁺ Controls	3.3 ± 3.9	4.3 ± 4.3
	DCD ⁻	3.9 ± 4.4	4.5 ± 4.2
	DCD ⁻ Controls	5.2 ± 4.8	6.0 ± 4.2
Free Time Play	DCD ⁺	16.3 ± 2.6	18.1 ± 4.3
	DCD ⁺ Controls	17.2 ± 3.7	17.4 ± 3.1
	DCD ⁻	14.8 ± 3.9	15.3 ± 5.0
	DCD ⁻ Controls	17.3 ± 2.8	16.7 ± 3.0
Inactivity	DCD ⁺	3.5 ± 3.0	3.3 ± 2.5
	DCD ⁺ Controls	1.9 ± 1.7	2.7 ± 1.3
	DCD ⁻	2.9 ± 2.2	3.2 ± 2.0
	DCD ⁻ Controls	2.3 ± 1.5	2.7 ± 1.6
Total Activity	DCD ⁺	21.7 ± 5.5	22.4 ± 6.4
	DCD ⁺ Controls	20.5 ± 6.7	21.7 ± 6.9
	DCD ⁻	18.7 ± 7.2	19.1 ± 7.4
	DCD ⁻ Controls	22.5 ± 6.5	22.8 ± 5.9

* Significant differences ($p < 0.05$) between times for the same group.

a Significant differences ($p < 0.05$) between DCD⁺ and DCD⁺ controls for the same time.

b Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻ for the same time

c Significant differences ($p < 0.05$) between DCD⁺ and DCD⁻ controls for the same time

d Significant differences ($p < 0.05$) between DCD⁺ controls and DCD⁻ for the same time

e Significant differences ($p<0.05$) between $DCD^{+}_{controls}$ and $DCD^{-}_{controls}$ for the same time
f Significant differences ($p<0.05$) between DCD^{-} and $DCD^{-}_{controls}$ for the same time

Table 12. Mean scores (mean \pm SD) for CSAPPA components in Time 1 and Time 2 for all groups.

		Time 1	Time 2
CSAPPA Adequacy	DCD^{+}	22.3 \pm 1.7	20.8 \pm 2.8
	$DCD^{+}_{Controls}$	19.2 \pm 2.5	22.7 \pm 3.5
	DCD^{-}	20.5 \pm 3.3	21.6 \pm 3.6
	$DCD^{-}_{Controls}$	22.0 \pm 3.9	22.6 \pm 3.8
CSAPPA Predilection	DCD^{+}	28.7 \pm 4.4	27.2 \pm 4.7
	$DCD^{+}_{Controls}$	26.2 \pm 3.8	30.5 \pm 5.0
	DCD^{-}	27.7 \pm 5.4	27.6 \pm 4.9
	$DCD^{-}_{Controls}$	28.4 \pm 4.7	30.2 \pm 4.9
CSAPPA Enjoy PhysEd	DCD^{+}	10.9 \pm 1.1	9.5 \pm 2.8
	$DCD^{+}_{Controls}$	11.0 \pm 1.5	11.2 \pm 1.4
	DCD^{-}	9.8 \pm 1.6	10.0 \pm 1.5
	$DCD^{-}_{Controls}$	11.2 \pm 1.5	10.8 \pm 1.9
CSAPPA Total	DCD^{+}	61.9 \pm 5.9	57.5 \pm 9.2
	$DCD^{+}_{Controls}$	56.4 \pm 6.1	64.4 \pm 8.5
	DCD^{-}	57.9 \pm 8.4	59.2 \pm 8.0
	$DCD^{-}_{Controls}$	61.7 \pm 8.3	63.6 \pm 8.2

* Significant differences ($p<0.05$) between times for the same group.

a Significant differences ($p<0.05$) between DCD^{+} and $DCD^{+}_{controls}$ for the same time.

b Significant differences ($p<0.05$) between DCD^{+} and DCD^{-} for the same time

c Significant differences ($p<0.05$) between DCD^{+} and $DCD^{-}_{controls}$ for the same time

d Significant differences ($p<0.05$) between $DCD^{+}_{controls}$ and DCD^{-} for the same time

e Significant differences ($p<0.05$) between $DCD^{+}_{controls}$ and $DCD^{-}_{controls}$ for the same time

f Significant differences ($p<0.05$) between DCD^{-} and $DCD^{-}_{controls}$ for the same time

4.3.5. Discussion

The present is the first study to examine the efficacy of a motor skill and exercise training programme in improving motor proficiency in children with and without DCD. The results showed that the adopted intervention significantly improved the BOTMP-*sf* scores in both $^{+}DCD_I$ and $^{-}DCD_I$ children. However, $^{+}DCD_I$ children, improved their motor competence (as measured by the BOTMP-*sf*) by 21.3% as opposed to only 4.9% improvement demonstrated by their $^{-}DCD_I$ peers.

These findings are consistent with the scarce previous data suggesting that exercise intervention programmes designed to combat DCD symptoms have produced positive outcomes (Fragala-Pinkham et al., 2005, Kaufman and Schilling, 2007). Despite this, however, interventions involving motor skills and exercise training for children with DCD are often overlooked (Hillier, 2007). The present results provide strong evidence in support of multidisciplinary intervention approaches that include general indicators of activity participation and overall health status of children with DCD (Hillier, 2007). The improvement observed herein for the $^{+}DCD_I$ group is in accordance with previous findings (Peters and Wright, 1999) showing a significant increase in the motor competence of children with DCD after a 10-week interdisciplinary intervention programme. Similar findings were observed following a 14-weeks exercise training intervention programme in children with various developmental disorders (Fragala-Pinkham et al., 2005).

The observed improvements in the BOTMP-*sf* scores of children with DCD may be explained by the fact that the utilised intervention involved practicing specific tasks (Table 9) which are related to skill enhancement. The national education curriculum allows for just two weekly PE sessions that are comprised mainly of group sporting activities (e.g., soccer, basketball) requiring pre-acquired proficiency in a variety of motor skills. In contrast, the motor skills and exercise programme introduced in this study focused on the basic components of motor competence. Based on the present results, this approach was more successful for improving motor efficacy in children with and without DCD. Moreover, participating in structured non-competitive exercise sessions, such as our intervention programme, may have prevented exclusion of children

with DCD by their peers, as often is the case in competitive sport settings (Poulsen and Ziviani, 2004). This is further supported by evidence showing that motor incompetence of children with DCD can be better treated if exercise intervention programmes are applied in settings involving social interaction compared to programmes in isolated environments (i.e. school vs. home based) (Fragala-Pinkham et al., 2005).

It is noteworthy that the improvement observed in the current BOTMP-*sf* scores for the ⁺DCD₁ and ⁻DCD₁ was not apparent in the control groups, which suggests that the standard Greek PE curriculum was insufficient to promote skill development. Indeed, a recent study (Koutedakis and Bouziotas, 2003) demonstrated that the Greek PE curriculum does not achieve the required levels of motor and cardiorespiratory fitness with potential effect on children's health. This may be one reason why Greek children demonstrate increased prevalence rates for obesity, decreased physical activity participation, and low aerobic fitness levels (Flouris et al., 2008, Koutedakis et al., 2005).

In line with published data (O'Beirne et al., 1994, Tsiotra et al., 2006), the present children with DCD demonstrated increased BMI and lower levels of cardiorespiratory fitness, leg explosive power and speed. Indeed, we have recently shown that DCD is related to an increased cardiovascular disease risk (Cairney et al., 2005, Tsiotra et al., 2009) due to the tendency of these children to avoid physical activities; a result of their lack of motor competence and low self esteem (Hay and Missiuna, 1998). It is necessary, therefore, to develop pediatric intervention strategies for DCD in an effort to prevent the aforementioned increased CVD risk that may arise in later years (Faught et al., 2005, Flouris et al., 2003, Tsiotra et al., 2006).

It is reasonable to assume that the lack of significant differences in the physical fitness parameters between T1 and T2 may be due to the relatively short duration of the programme. The validity of self-administered questionnaires, such as the PQ, which has been questioned for use with paediatric populations (Sallis and Saelens, 2000), may explain the lack of significant differences between children with and without DCD regarding participation in physical activities. Indeed, children with and without DCD responded similarly ($p > 0.05$) in both the PQ and the CSAPPA scale. This is a

surprising finding since it is well known that participation in physical activities and perceptions towards physical activity are significantly different between children with and without DCD (Faught et al., 2005). Furthermore, the CSAPPA scale utilised herein was a means of assessing the activities of daily living of children with DCD. Our results showed no significant differences in the scores of children with and without DCD, even after the exercise training programme. This may reflect that the CSAPPA scale is an inappropriate tool to assess the activities of daily living, since it is more physical activity specific. Activities of daily living involve a number of routines (eating, dressing, personal hygiene, play, e.t.c) and it would be reasonable to include at least a number of these in future studies.

Within these limitations, it is concluded that an 8-week motor skill and exercise training programme was successful in improving motor proficiency in elementary school children, particularly in those classified as DCD positive. Future studies should integrate larger samples of children with DCD and interventions of longer duration in order to develop the much-needed pediatric intervention strategies for DCD.

Study 4. Towards a comprehensive appraisal and screening of children with Developmental Coordination Disorder

(This study is under review)

4.4.1. Introduction

Poor motor coordination in children is a well-recognized developmental problem because withdrawal or exclusion from play, sports, and games significantly affects children's social interaction, skill practice, fitness, health, and – ultimately – quality of life (Koutedakis et al., 2005, Sallis et al., 1988). Therefore, considerable concern has been expressed for the children whose deprived motor abilities put them at risk for withdrawal or exclusion from physical activity (Cairney et al., 2005).

Developmental Coordination Disorder (DCD), a term describing individuals with impaired motor function, affects 5-19 % of pediatric populations worldwide (American Psychiatric Association, 1994, Flouris et al., 2003, Henderson and Henderson, 2002, Tsiotra et al., 2006). The direct symptoms of DCD include poor motor coordination, handwriting difficulties, academic and behavioral problems, heightened anxiety, and psychosocial adjustment problems (American Psychiatric Association, 1994). More importantly, however, it was recently showed that DCD is related to an increased cardiovascular disease risk [CVD (Cairney et al., 2005, Tsiotra et al., 2009)] due to the tendency of DCD children to avoid physical activities; a result of their lack of motor competence and low self esteem (Hay and Missiuna, 1998). However, the literature contains only few large-scale projects that were conducted mainly in North American populations, while it remains unclear which modes of physical activity mediate the relationship between DCD and CVD; information that is necessary in order to design effective physical activity interventions.

It is well-known that children with DCD may stay unnoticed for many years because the signs and symptoms of this condition are not always apparent to professionals from educational settings (Hay and Missiuna, 1998). It is necessary, therefore, to develop strategies that identify individuals with DCD early in life, in an effort to prevent the aforementioned increased CVD risk that may arise in later years (American Psychiatric Association, 1994, Denckla, 1984, Faught et al., 2005, Henderson and Henderson, 2002, Rasmussen and

Gillberg, 2000, Tsiotra et al., 2006). Indeed, the benefits on quality of life and minimization of symptoms through therapeutic interventions for DCD children are increased if the screening and identification takes place early in life (Hay, 1992, Hay et al., 2004). However, widely accepted DCD screening methods such as the Bruininks Oseretsky Test of Motor Proficiency [BOTMP (Bruininks, 1978)] or the Movement Assessment Battery for Children (Henderson and Sugden, 1992) are neither practical nor cost-effective. The Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) scale (Hay, 1992) has been previously used as a cost-effective and practical proxy of the short form of the BOTMP test (BOTMP-sf) in screening for DCD (Hay and Missiuna, 1998). When compared to BOTMP, the CSAPPA has shown adequate sensitivity and specificity in identifying DCD children (Hay et al., 2004). In the present large-scale European project, our objectives were (i) to test the hypothesis that DCD is linked with a higher risk for CVD, (ii) to identify the modes of physical activity that mediate the relationship between DCD and CVD and (iii) to evaluate the CSAPPA scale as a potential tool for identifying Greek DCD children.

4.4.2. Methods

4.4.2.1. Participants

The study protocol conformed to the standards set by the Declaration of Helsinki and was approved by the University's Research Ethics Committee and the Greek local educational authorities. Recruitment for participants took place in 10 randomly-chosen elementary schools in the cities of Trikala (central Greece) and Patra (southern Greece). All 1219 students of these schools were invited to participate in the study and 574 volunteers gave parental written informed consent after full explanation of the procedures. The 574 participants (Boys: $n=300$; age: 11.46 ± 1.92 years; BMI: 20.38 ± 3.79 , Girls: $n=274$; age: 11.45 ± 0.98 years; BMI: 19.50 ± 3.18) were typical middle-class urban dwellers who reported to be free of any medical conditions and participated in physical education classes regularly.

4.4.2.2. Procedures

All measurements took place over the last 5 years. Data for this study were collected from studies 1, 2 and 3 of the present research work. Health related assessments included anthropometry, cardiorespiratory fitness and motor proficiency via the short form of the Bruininks-Oseretsky Test of Motor Proficiency (BOTMP-sf). Participants also completed a physical activity participation questionnaire (PQ) and the Children's Self Perception of Adequacy in and Predilection for Physical Activity scale (CSAPPA).

4.4.2.2.1. Anthropometry

Body mass was measured to the nearest 0.1 kg using an electronic scale (TANITA, TBF-521, Japan). Height was measured with a standardised stadiometer to the nearest, 0.1 cm (SECA-GYMNA, Germany). Body Mass Index (BMI) was calculated as $\text{weight} \cdot \text{height}^{-2}$ ($\text{kg} \cdot \text{m}^{-2}$).

4.4.2.2.2. Cardiorespiratory Fitness

This test required from the participants to run back and forth between two fixed lines 20 meters apart. The children had to follow a prescribed signal emitted from an audiocassette player. The frequency of the signal increased by $0.5 \text{ km} \cdot \text{h}^{-1}$ each minute from a starting speed of $8.5 \text{ km} \cdot \text{h}^{-1}$. Several shuttle runs make up each stage of the test and pupils are instructed to keep pace with the signals for as long as possible. The test was terminated when each participant could not follow the prescribed pace for three consecutive signals. The maximal speed attained was then used to calculate maximal oxygen uptake ($\dot{V}\text{O}_{2\text{max}}$) in $\text{ml} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ (Flouris et al., 2005).

4.4.2.2.3. Bruininks-Oseretsky Test of Motor Proficiency-short form (BOTMP-sf)

This test was performed using standardised procedures (Bruininks, 1978) in a separate classroom or in the school's gymnasium behind a curtained barrier to ensure confidentiality. BOTMP-sf (APPENDIX 4) was used to assess criterion A *“Performance in daily activities that require motor coordination is substantially below that expected given the person's chronological age and measured intelligence. This may be manifested by marked delays in achieving motor milestones (eg, walking, crawling, and sitting), dropping things, “clumsiness,”*

poor performance in sports, or poor handwriting.” of the DSM-IV (American Psychiatric Association, 1994). The BOTMP-*sf* is an individually administered test that assesses the gross and fine motor proficiency of children. The BOTMP-*sf* was utilized for administrative and time-efficiency reasons. The test is comprised of 14 items, which examine general motor skills and has been previously validated for elementary school-age children (Bruininks, 1978, Bruininks and Bruininks, 1977). Tests administered include running speed and agility, balance, bilateral coordination, strength, upper-limb coordination and dexterity, and response speed. Motor incoordination was established based on standardised cut-offs. An age matched standard score equal to or below 37 was used to classify suspect cases with (DCD⁺) and without (DCD⁻) DCD (Bruininks, 1978).

4.4.2.2.4. Physical Activity Participation Questionnaire (PQ)

Physical activity participation was measured via the Participation Questionnaire (PQ) (Hay, 1992). This is a 61-item self administered questionnaire that assesses children's participation levels in free-time play, seasonal recreational activities, school sports, community based team sports and clubs, and private sports dances and lessons which requires approximately 20 minutes to complete. Participation in organised activities includes a 1-year period, and free play is considered from typical activity choices. Subtotal calculations are available for free play, organised play and inactivity. Total participation in activity is estimated as the sum of organised and free play activities. This test has been proven to be a reliable tool for accessing physical activity in elementary school children and has produced a test–retest reliability of 0.81 (Hay, 1992). In line with other self administered physical activity questionnaires, the PQ has demonstrated moderate criterion validity (0.62) (Hay, 1992, Hay and Donnelly, 1996) and has been used in the past to access physical activity engagement in DCD⁺ children (Cairney et al., 2005). In the Greek version of the PQ, certain winter activities that the North American children are likely to engage in were replaced by activities equivalent in energy cost which are popular in the specific settings of Greece (McArdle et al., 2003).

4.4.2.2.5. Children's Self Perception of Adequacy in and Predilection for Physical Activity (CSAPPA) Scale

The CSAPPA designed initially to assess children at risk for hypoactivity, (Hay, 1992) has been found to be a reliable tool for assessing children at risk for DCD (Hay et al., 2004). It is a 20-items test designed to measure children's self perceptions of their adequacy in performing and their desire to participate in age-related physical activities. This questionnaire is presented with 3 imbedded factors in terms of scoring: i) Adequacy, ii) Predilection and iii) Enjoyment of physical education class. Overall, CSAPPA measures generalized self-efficacy toward physical activities (Hay and Missiuna, 1998, Hay et al., 2004). The Greek version of CSAPPA was created as a comprehensive translation of the original English version and both can be found in APPENDIX 5.

4.4.3. Questionnaire Reproducibility

To investigate the reproducibility of the PQ and CSAPPA questionnaires, 36 children (17 boys; 19 girls; age: 10.3 ± 5.3 years; BMI: 20.9 ± 3.5) completed the previously-described questionnaires twice within an 8-week period. Results showed no significant difference ($p > 0.05$) between the mean values for CSAPPA (60.2 ± 8.1 vs. 63.8 ± 8.2) and PQ total activity participation (22.0 ± 6.5 vs. 22.5 ± 6.1) recorded. Correlation coefficients between the two trials for both questionnaires were significant at $p < 0.001$. Ninety five percent limits of agreement for CSAPPA and PQ were 3.6 ± 14.1 and 0.5 ± 11.2 , respectively (Bland and Altman, 1986).

4.4.4. Statistical Analysis

Prevalence rates and accompanying confidence intervals were calculated for diagnosed DCD, overweight, obesity, low cardiorespiratory fitness and sedentary lifestyle. DCD was defined as BOTMP-sf standard score ≤ -1.64 (Bruininks, 1978). The prevalence rates for overweight and obesity based on BMI data were calculated according to age- and sex-specific cut-offs proposed by the International Obesity Task Force (Cole et al., 2000). Low cardiorespiratory fitness was defined as $\dot{V}O_{2\max}$ below the age- and sex-specific median value (Flouris et al., 2007). Similarly, a sedentary lifestyle was defined as PQ values for organised activity, free play and total activity below the age-

and sex-specific median value as well as values for inactivity above the age- and sex-specific median value.

Performing DCD-specific statistics using data from the entire sample would reflect the disparate proportions of the DCD⁺ and DCD⁻ groups (sample sizes of the DCD⁺ and DCD⁻ groups were 85 and 489, respectively). For instance, 15 DCD⁺ and 24 DCD⁻ children in the entire sample were diagnosed with obesity, suggesting that obesity was more prevalent in DCD⁻ children. And yet, the corresponding prevalence rates for obesity in DCD⁺ and DCD⁻ children were 18% and 5%, respectively. In order to alleviate the effect of the difference in sample sizes when comparing DCD⁺ and DCD⁻ children, a subsample was created that included the 85 DCD⁺ children as well as 85 randomly-chosen sex- and age-matched DCD⁻ children and three further analyses were conducted on these 170 children. The first analysis included chi-square tests used to detect differences in prevalence rates for the various CVD risk factors between DCD⁺ and DCD⁻ children. The second analysis included a one-way analysis of variance (ANOVA) to compare the values for BMI, $\dot{V}O_{2max}$, scores for organised activity, free play, inactivity, and total activity between DCD⁺ and DCD⁻ children used to further confirm the findings of this analysis. The third analysis included two hierarchical linear regression models (i.e., regression analysis where independent variables are inserted in a pre-specified sequence to observe changes in regression coefficients between successive regression models) to investigate the theoretical model linking motor competence to two risk factors for CVD (i.e. obesity and low cardiorespiratory fitness) through physical activity participation. In the first regression model, the BOTM-sf was set as the dependent variable, while age, sex, BMI and the components of participation in physical activity questionnaire (i.e., organised activity, free play, and inactivity) were defined as independent variables. The hierarchy of the independent variables was adjusted so that the initial stage included age, sex and BMI, while organised activity, free play, and inactivity scores were inserted one by one in subsequent stages in order to observe differences in regression coefficients. The second hierarchical regression model used the same procedure with $\dot{V}O_{2max}$ as independent variable instead of BMI.

In order to evaluate the CSAPPA scale as a potential tool for identifying Greek children with DCD, data from the entire sample were used. Receiver-operator characteristic (ROC) curve analysis was adopted to establish a positivity criterion for CSAPPA. Selection of the optimal cut-off for each population was based on the classification with the lowest simultaneous frequency of false-positives and false-negatives, similarly to the original CSAPPA (Hay et al., 2004). Thereafter, the efficacy of the different positivity criteria of CSAPPA was compared to the gold standard BOTMP-*sf*. Calculated sensitivity and specificity with corresponding 95% confidence intervals (CI) were used to determine the efficacy of the designated cut-off in screening for DCD. Sensitivity was defined as the proportion of subjects with DCD (BOTMP-*sf* standard score ≤ 37) that demonstrated a CSAPPA score below the determined positivity criterion. Specificity was defined as the proportion of subjects tested negative for DCD (BOTMP-*sf* standard score > 37) that revealed a CSAPPA score above the determined positivity criterion. Cohen's Kappa statistic was used to evaluate the agreement between the CSAPPA cut-off score and BOTMP-*sf*. All statistical analyses were performed with SPSS (version 14.0.1, SPSS Inc., Chicago, Illinois) and NCSS (version 2000, NCSS Statistical Software, Kaysville, Utah) statistical software packages. The level of statistical significance was set at $p < 0.05$.

4.4.5. Results

The prevalence rates of cardiovascular disease risk factors in the subsample of 85 DCD⁺ and 85 DCD⁻ children are demonstrated in *Table 13*.

Table 13. Prevalence rates \pm CI of cardiovascular disease risk factors in the subsample of 85 DCD ⁺ and 85 DCD ⁻ children and chi-square comparisons.			
	DCD ⁺	DCD ⁻	χ^2 (p value)
Overweight	35.3 \pm 0.1	20.0 \pm 0.1	3.6 (0.05)
Obesity	17.7 \pm 0.1	6.8 \pm 0.1	5.0 (0.03)*
Low cardiorespiratory fitness	68.2 \pm 0.1	35.3 \pm 0.1	8.9 (0.01)*
PQ			
Organised activity	47.1 \pm 0.1	48.2 \pm 0.1	0.0 (0.91)
Free play	60.0 \pm 0.1	32.9 \pm 0.1	6.7 (0.01)*
Inactivity	52.9 \pm 0.1	41.2 \pm 0.1	1.25 (0.26)
Total activity	71.0 \pm 0.1	62.4 \pm 0.1	0.43 (0.51)

* = statistically significant at $p < 0.05$.

DCD⁺ = Positive diagnosis for Developmental Coordination Disorder; DCD⁻ = Negative diagnosis for Developmental Coordination Disorder; PQ= Participation Questionnaire

Chi-square comparisons demonstrated that the majority of the children that were overweight, obese, and showed low cardiorespiratory fitness and low participation in free play were DCD⁺ ($p < 0.05$). Similar results were derived from the ANOVA used to compare the values for BMI, $\dot{V}O_{2max}$, organised activity, free play, inactivity, and total activity between DCD⁺ and DCD⁻ children (*Table 14*).

Table 14. Mean±SD values of the assessed parameters in the subsample of 85 DCD⁺ and 85 DCD⁻ children and ANOVA comparisons.

		DCD ⁺	DCD ⁻	F (p value)
Weight (kg)		48.0±12.3	43.5±9.7	6.5 (0.01)*
Height (m)		1.5±0.1	1.5±0.1	0.01 (0.98)
BMI		21.8±4.6	19.7±3.2	11.2 (<0.01)*
$\dot{V}O_{2max}$		32.3±5.2	36.2±5.9	19.8 (<0.01)*
BOTMP-sf		31.1±5.9	56.2±10.2	386.9(<0.01)*
CSAPPA				
	Adequacy	20.6±4.1	22.6±3.7	11.4 (<0.01)*
	Predilection	27.5±5.0	30.0±4.7	11.1 (<0.01)*
	Enjoyment	10.6±1.8	11.2±1.4	4.3 (0.04)*
	Total	58.7±8.8	63.7±8.0	14.9 (<0.01)*
PQ				
	Organised activity	5.2±4.3	5.3±4.5	0.01 (0.91)
	Free play	16.0±3.9	17.3±3.5	5.4 (0.02)*
	Inactivity	4.0±2.5	3.2±2.1	4.2 (0.04)*
	Total activity	21.2±6.7	22.0±6.4	1.8 (0.18)

* statistically significant at $p < 0.05$.

DCD⁺ = Positive diagnosis for Developmental Coordination Disorder; DCD⁻ = Negative diagnosis for Developmental Coordination Disorder; $\dot{V}O_{2max}$ = maximal oxygen uptake; BOTMP-sf =Bruininks Oseretsky Test of Motor Proficiency-short form; CSAPPA =Children's Self Perception of Adequacy in and Predilection for Physical Activity scale; PQ= Participation Questionnaire.

Specifically, it was observed that DCD⁺ demonstrated significantly increased weight, BMI and inactivity, as well as significantly decreased $\dot{V}O_{2max}$, BOTMP-sf, CSAPPA indices, and participation in free play ($p < 0.05$).

The hierarchical regression models demonstrated that BMI and $\dot{V}O_{2max}$ were significantly associated with motor competence ($p < 0.05$). Moreover, this

relationship was mediated through inactivity given that the coefficient of determination increased significantly ($p<0.05$) in both analyses when inactivity was inserted in the regression models (Table 15).

Table 15. Unstandardised regression coefficients and standard errors [β (std. error)] from hierarchical regression models associating BMI, $\dot{V}O_{2\max}$ and parameters of physical activity participation in DCD⁺ children. Data for controlling covariates age and sex are not illustrated.

IV	R ²	DV: BOTMP-sf			
Constant		42.29 (7.85)	41.52 (7.87)	42.85 (8.75)	41.24 (8.53)
BMI	0.34	-0.35 (0.14)†	-0.37 (0.14)†	-0.37 (0.14)†	-0.31 (0.14)†
Organised activity	0.36		0.16 (0.14)	0.18 (0.15)	0.19 (0.15)
Free play	0.36			-0.06 (0.17)	-0.11 (0.17)
Inactivity	0.44*				-0.60 (0.25)
Constant		20.35 (7.26)	19.45 (7.37)	22.25 (8.08)	23.59 (7.90)
$\dot{V}O_{2\max}$	0.40	0.40 (0.12)†	0.40 (0.12)†	0.41 (0.12)†	0.36 (0.12)†
Organised activity	0.41		0.11 (0.14)	0.16 (0.15)	0.18 (0.15)
Free play	0.42			-0.15 (0.17)	-0.18 (0.17)
Inactivity	0.48*				-0.56 (0.25)†

ANOVA for all models was statistically significant at $p<0.05$.

* R² change indices significant at $p<0.05$.

† dependent variable statistically significant predictors at $p<0.05$.

DCD⁺ = Positive diagnosis for Developmental Coordination Disorder; IV= independent variable; R²= coefficient of determination for each model; DV= dependent variables;

BOTMP-sf =Bruininks Oseretsky Test of Motor Proficiency-short form $\dot{V}O_{2\max}$ = maximal oxygen uptake.

Figure 6 illustrates the ROC curve for CSAPPA in the entire sample. The analysis indicated an optimal CSAPPA cut-off at 62 points that yielded a sensitivity of 0.64 and a specificity of 0.60. The area under the ROC curve was 0.67 ± 0.03 ($p<0.001$). Cohen's Kappa statistic demonstrated significant agreement between the CSAPPA positivity criterion and BOTMP-sf diagnosis ($p<0.001$). Therefore, children reporting a cumulative CSAPPA score of ≤ 62 were considered DCD⁺, while children reporting cumulative CSAPPA scores >62 were considered DCD⁻. Eighty five children (0.17 ± 0.03) were diagnosed as DCD⁺ based on BOTMP-sf. Using the designated cut-off score, the CSAPPA scale identified correctly 54 children and it misdiagnosed 195 children as DCD⁺ that were in fact DCD⁻.

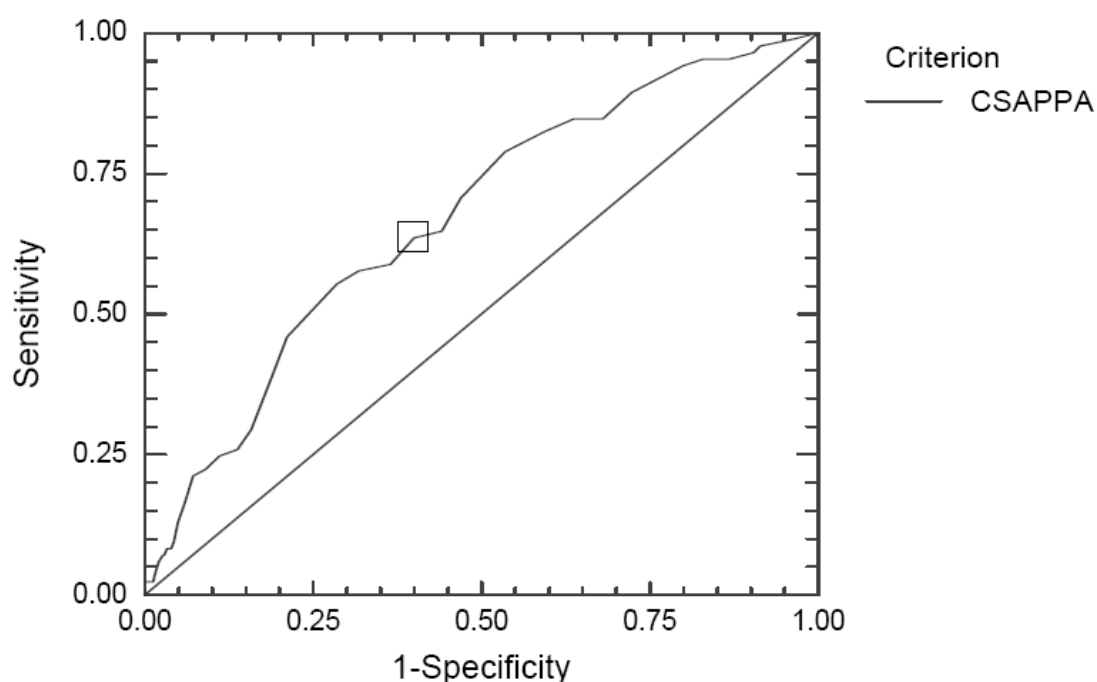


Figure 6. ROC curve for CSAPPA and BOTMP-sf in the entire sample. Squared area designated CSAPPA cut-off score at 62.

4.4.6. Discussion

Recent data from our and other groups suggested that DCD is associated with an increased risk for CVD (Cairney et al., 2005, Cairney et al., 2007, Faught et al., 2005, Hands and Larkin, 2006, Reeves et al., 1999, Tsiotra et al., 2006). However, the literature contains only few large-scale projects that were conducted and the majority of these are from a North American population. In this light, the first aim of this large-scale European project was to test the hypothesis that DCD is linked with a higher risk for CVD. The present results confirm this hypothesis showing that DCD⁺ children exhibited increased prevalence rates for overweight and obesity as well as lower cardiorespiratory fitness and participation in free play than their DCD⁻ peers. As increased overweight and obesity values as well as low cardiorespiratory fitness levels among normal pediatric populations have been linked to adulthood morbidity risk from CVD factors (Boreham et al., 2001), our findings highlight that the present DCD⁺ sample may possibly end up with CVD later in life.

A second aim was to identify the modes of physical activity that mediate the relationship between DCD and CVD. Based on the present results, this

relationship is mediated by inactivity and not by actual participation in different modes of physical activity. In other words, in order for the CVD risk of DCD⁺ children to diminish, it is important that they become frequently active, regardless of the activity mode (i.e., in organised or free play structure). These results are of particular value for designing effective physical activity interventions. Previously published reports advocate that childhood inactivity may lead to an inactive lifestyle during adulthood, while physical activity levels are widely accepted as an autonomous risk factor for several chronic diseases including CVD (Cairney et al., 2007, Flouris et al., 2008, Koutedakis et al., 2005). Therefore, identification of physical activity or inactivity levels may facilitate early remedial strategies (Flouris et al., 2008) for children with DCD.

In order to evaluate the CSAPPA scale as a potential tool for identifying DCD⁺ children, ROC curve analysis was adopted to identify the most appropriate cut-off that produced the lowest frequency of false-positive and false-negative cases. A CSAPPA positivity criterion at ≤ 62 was found to be an appropriate cut-off for the screening of DCD⁺ cases in the current population. These results are consistent with previous studies suggesting that children with low CSAPPA scores are significantly clumsier (Faught et al., 2002, Hay et al., 2004, Hay and Missiuna, 1998). Despite capturing some children with low self-perceptions for reasons other than DCD, the CSAPPA scale appears to identify the majority of those with DCD demonstrating significant agreement with the reference standard BOTMP-*sf*. According to the sensitivity and specificity established herein, in a hypothetical population of 1000 children, the CSAPPA scale would identify correctly 94/148 children. Also, based on the CSAPPA false positive rate, the BOTMP-*sf* would be required to confirm a diagnosis of DCD in 433 children of the total 1000 children. As the total cost of screening such a large population using the BOTMP-*sf* would reach a minimum of \$100000, the use of the CSAPPA scale would reduce the total cost for DCD screening by approximately 43.3%. This cost reduction is paramount especially for countries such as Greece that show an increased prevalence for DCD compared to internationally reported data (American Psychiatric Association, 1994, Henderson and Henderson, 2002). Indeed, in the present large-scale project a

14.8% prevalence for DCD was found, while internationally reported prevalences usually reach a 10% rate (American Psychiatric Association, 1994).

Given that participation in physical activity changes throughout the year (Christodoulos et al., 2006), the present data may have been influenced by the fact that all measurements took place during the start of the academic year. Furthermore, results from the PQ utilized herein represent subjective indicators of physical activity participation. While the use of self-assessment questionnaires has received criticism (Sallis and Saelens, 2000), the PQ has been successfully used in DCD⁺ children in the past (Cairney et al., 2005, Faught et al., 2005). In conclusion, the results of this large-scale European project demonstrate that children with DCD are at high risk for developing CVD later in life due to their increased inactivity and that the CSAPPA scale is a valid, practical and a cost-effective screening instrument for DCD. These findings suggest that physical activity should receive paramount attention in the design of public health interventions targeting DCD children. As the majority of physical activity in childhood takes place in organised programmes outside of school, multiple approaches will likely be required, including policy changes, environmental planning and educational efforts in family, school and community, in order to provide DCD children with substantial amounts of physical activity, sufficient to result in multiple health benefits.

CHAPTER 6: GENERAL DISCUSSION

The first part of this work aimed at identifying the prevalence of DCD in Greek-school-aged children, investigate whether children with DCD may be at risk for obesity and cardiorespiratory fitness and compare this information with relevant data from Canada. The prevalence rate for DCD was found to be 19%. Prevalence rates in North Europe and North America range between 6 and 10% of all school-aged children (American Psychiatric Association, 1994, Henderson and Henderson, 2003), while the use of strict criteria of the DSM-IV in a recent study in the UK has revealed a DCD prevalence rate of only 1.8% (Lingam et al., 2009). However, this study did not utilise a complete battery test to assess DCD and thus may have missed a number of cases. This discrepancy may be partly attributed to the use of the BOTMP-*sf* test to identify DCD pupils in the present sample. Despite its extensive validation and use in North America, the BOTMP-*sf* has not been previously employed in a sample of Greek children above the age of 8 and certain items of the BOTMP-*sf* (i.e. ball catching, sorting cards) may not be the most appropriate indicators of motor coordination in Greek children (Cintas, 1995), while the cut-off scores indicating probable DCD may require modification (Rosblad and Gard, 1998). In addition, the high prevalence rate found herein reflects children with both borderline DCD and severe DCD. Categorisation of children with DCD according to the severity of their signs and symptoms may be of great importance since analogous intervention strategies are currently applied for mild or severe cases (Gueze et al., 2001). However, published data on younger Greek samples found BOTMP-*sf* to be a valid test of motor proficiency (Kambas and Aggeloussis, 2006).

Criterion B of the DSM-IV suggests that activities of daily living may add substantial information in the diagnoses of DCD (Sugden, 2006). However, activities of daily living are not quantified by the DSM-IV criteria which may cause confusion as to what should be measured and how (Gueze et al., 2001, Lingam et al., 2009). In the present study the use of the CSAPPA scale as a means of assessing the activities of daily living may have provided with additional information regarding the activities of children with DCD, however, the CSAPPA scale was not originally designed to assess activities of daily living of

children with DCD. Rather, it assesses perceptions and adequacy of children in general with regard to specific activities that are mentioned in the questionnaire. Activities of daily living involve a variety of actions [dressing, hygiene, riding a bike e.t.c. (Summers et al., 2008)], but the CSAPPA scale only focuses on energetic activities undertaken during school, physical education, or at free time. Nonetheless, even if the scale may not capture all the activities of daily living of children with DCD, it can address difficulties with physical activity engagement.

Another contribution of the present investigation is the significantly higher prevalence of girls with DCD compared to boys. This comes in contrast to existing literature advocating girls:boys ratios ranging from 1:2 (Sugden and Chambers, 1998) to 1:4 (Kadesjo and Gillberg, 1999). This discrepancy may be attributed to the fact that, contrary to the majority of published reports, a large sample of children was screened for the purposes of the present work. Furthermore, as society's motor-proficiency expectations for boys are higher than girls, the previously reported increased DCD prevalence for boys may have been attributed to the fact that more boys than girls get referred with functional difficulties, indicating a society bias towards boys.

The present results clearly suggest that children with DCD have an increased risk for being obese with low levels of cardiorespiratory fitness. This was not surprising since children with motor deficits, including DCD, are normally less physically active (Flouris et al., 2003, Hay and Missiuna, 1995). This may lead to long-term health risks, as the association between reduced physical activity and increased risk of chronic diseases is well established (Lee and Paffenbarger, 1994). Indeed, Greek schools seem to be unable to provide adequate stimuli for the improvement of key motor and cardiovascular fitness parameters through physical education curricula (Koutedakis and Bouziotas, 2003). The current data confirm published reports indicating increased prevalence in obesity among Greek paediatric populations (Bouziotas and Koutedakis, 2003). Results from the present study, also suggest that children with DCD demonstrate a greater propensity for clinical obesity and low cardiorespiratory fitness. Since physical fitness comprises of components besides body composition and cardiorespiratory fitness, there is still a need to

address whether the levels of the remaining fitness components (i.e., strength, speed) also compromise the health of children with DCD.

Results from the second study revealed a prevalence of DCD of about 8%, which is considerably lower than that reported in the first experiment of the present work. This discrepancy may be explained by several reasons. First, is the fact that children in study 1 were significantly younger than children in study 2 ($p<0.05$) and mainly attributed to girls rather than the boys (*Table 16*). It is known that children present differences in some cognitive processes such as selective attention and speed of information processing while they grow older. In fact, children use different information processing methods compared to adults in tasks that require planning and execution of movements, visuospatial working memory, object recognition memory, verbal learning and/or higher-level attention focusing (Sullivan et al., 2008). Ferrel-Chapus et al., (2002) argued that there is an advancement in the capability to integrate visual and proprioceptive afferent inputs with age which results in a more efficient motor performance in older children. So, even though serious effort was made to select schools that would represent pediatric populations between the ages of 10–to-12 in all studies, it seems that samples included children who were two-to-three months older than 12 years of age. It was not possible to exclude such cases since these children are permitted by the Greek school regulations to attend the same classes as their slightly younger counterparts.

Table 16. Mean age difference (mean \pm sd) between DCD⁺ children from studies 1 and 2.

	Study 1	N	Study 2	N	Sig.
Entire sample	11.1 \pm 0.90	61	12.0 \pm 1.23	12	0.005*
Boys	11.0 \pm 0.80	24	11.5 \pm 1.60	6	0.382
Girls	11.2 \pm 0.97	37	12.6 \pm 0.32	6	0.001*

* Significant differences ($p<0.05$) between DCD⁺ and DCD⁻ children from studies 1 and 2

High DCD prevalence rates have been identified in Greece before. Kourtessis et al., (2008) reported a 10.8% prevalence rate of Greek children with moderate coordination difficulties and another 1.6% with severe coordination difficulties. Other reasons could have also affected the present results. For example, there is an established relation between low birth weight

and DCD (Holsti et al., 2002) with prevalence rates of DCD in children born with low birth weight reaching 51%. However, this information is not available for the present samples.

The second study also confirmed previous reports which suggest that children with DCD demonstrate higher BMI and lower leg explosive power, speed and hand strength compared to children classified as non-DCD. Similar, but non-significant, results were observed for flexibility and cardiorespiratory fitness. These results suggest that children with DCD, who are generally inactive (Faught et al., 2005), may also have a greater risk for CVD diseases compared to their normal peers due to the exceeded accumulation of body fat which is associated with a BMI increase (Shvartz and Reibold, 1990). While BMI increases may explain a significant amount of performance variations in children with DCD, recent data advocate that childhood obesity is correlated with lower scores in standardised motor skills tests whereas overweight has no significant effect in skills performance (Cairney et al., 2005, D' Hodnt et al., 2009). However, it is yet to be determined whether DCD places the individual at risk for obesity or whether obesity substantially complicates the functional and skilled performance of children. Shaping the cause and causality relationship would assist in designing more effective strategies for children with DCD that would combat obesity with regular participation in activities that promote energy expenditure.

Findings from this second study also highlight the importance of controlling for body size parameters while testing the physical fitness performance of Greek children. Based on data from this study another paper has been published which addresses this issue (Nevill et al., 2009). Previous reports (Rowland, 2001) also stressed the importance of accounting for body size parameters before valid inference can be made for the performance of children in running and jumping activities. Available data suggest that excess body weight (i.e overweight and obesity) affects the performance of normal children in endurance events and places them at risk for CVD at a later stage in life (Ruiz et al., 2006). Even though previous studies on children with DCD have considered this issue (Haga, 2008) no data so far have had taken into account

body size parameters and their influence on physical fitness measures for children with DCD.

Finally, although this study revealed no significant differences in the cardiorespiratory fitness of DCD children compared to those without, the present sample exhibited lower values compared to international standards (Shvartz and Reibold, 1990). As optimal physical fitness is mainly achieved through physical activity participation (Caspersen et al., 1985), this study highlights the need for DCD children to engage in sufficient amounts of such participation.

In Study 3 the efficacy of a motor skill and exercise training intervention programme in improving motor proficiency in children with and without DCD was assessed. Results revealed that the exercise intervention improved the performance not only of the children with DCD but also of those without. While published data highlight the need for multidisciplinary interventions that incorporate various aspects of performance enhancement (Hillier, 2007) the current data are the first to consider exercise as a means for enhancing performance in a group of children with DCD.

The intervention may have been effective because children were exercising in structured group activities where competition with peers was not evident. Children with DCD are considered generally inactive and are known to experience difficulties to participate in physical activities with their normal peers (Poulsen and Ziviani, 2004). It has been argued that the actual condition of DCD prevents them from sport participation and lead them to have negative feelings about themselves (Hellgren et al., 1994). However, the present programme allowed plenty of time for each child to participate in every activity as well as to correct possible mistakes in the execution of skills through guidance by the physical educator.

The lack of statistical improvements in fitness components may be attributed to the inadequate number of sessions per week. Fitness enhancement requires regular (i.e. more than three times/week) exercise participation before even the smallest amounts of improvement are seen in the individual's performance (Janssen, 2007). In addition, the tasks and drills of the exercise programme were focused in improving skills that the children otherwise practised every day (running, jumping, balancing, ball handling e.t.c). This

assisted in helping them to adjust to the present circumstances (i.e. three times /week exercise) with the least possible anxiety and nervousness.

Although the present exercise intervention provided evidence for the importance of exercise programmes in improving the functional difficulties that DCD poses to children, it did not include a strategy to combat the actual impairment. This programme rather improved the ability of children with DCD to function in mandatory everyday tasks during school hours and especially during physical education. Multidisciplinary programmes that combine a strategy to combat the impairment, but that may also improve the quality of life of these children, are still needed.

Study 4 aimed to: (i) to test the hypothesis that DCD is linked with a higher risk for CVD, (ii) to identify the modes of physical activity that mediate the relationship between DCD and CVD and (iii) to evaluate the CSAPPA scale as a potential tool for identifying Greek DCD children. Previous research on DCD has related the condition to an increased cardiovascular disease risk (Cairney et al., 2006). However, available data concern only few large-scale projects that were conducted mainly in North American populations, while it still remains unclear which modes of physical activity mediate the relationship between DCD and cardiovascular disease risk. This information is necessary in order to design effective physical activity interventions.

The present results confirm the hypothesis that children with DCD exhibit increased prevalence rates for overweight and obesity as well as lower cardiorespiratory fitness and participation in free play than their non-DCD peers. This finding places them at risk for developing CVD at a later stage in life. Previous research has identified physical activity participation as a mediator for the relationship between DCD and CVD (Faught et al., 2005). Findings from the present study however, reveal that this relationship is mediated by inactivity and not by actual participation in different modes of physical activity. Also, since there is a tendency of inactive children to become inactive adults (Hands, 2008), the current results, highlight the importance of adopting physical activity participation interventions for children with DCD, irrespectively of the physical activity mode offered.

Another aim of this study was to evaluate the CSAPPA scale as a potential tool for screening children with DCD. The results confirm that a cut-off at ≤ 62 was the most appropriate score that produced the least false-positive and false-negative cases. Previous research has identified the CSAPPA scale as a valid instrument to be used for the identification of children with DCD (Faught et al., 2002, Hay et al., 2004, Hay and Missiuna, 1998). Despite the fact that the present findings are supported by previously published data, a more cautious treatment regarding its use is suggested. CSAPPA was originally designed to capture children at risk for hypoactivity (Hay, 1992). The 20-items of the CSAPPA questionnaire tend to examine the perceptions and attitudes of children with DCD towards different activities, rather than whether the child experiences difficulties with its coordination. Therefore, CSAPPA should be treated as a screening questionnaire that assesses children at risk for DCD or even "suspect" cases of DCD, since this group of children is known to experience difficulties with activity participation.

Finally, even though the CSAPPA scale is a cost-effective screening tool in comparison to other standardised tests such as the BOTMP (Bruininks, 1978) or the M-ABC (Henderson et al., 1992), it is of great value to add that the actual diagnoses of DCD with standardised measures cannot be substituted with non-formal tests. However, most of the school-based studies regarding identification of DCD cases require the massive screening of children, at least in Greece, where a typical class comprises of 20 to 22 pupils, who for time-consuming reasons should be assessed for DCD at the same time. It would rather be appropriate in such cases (large scale projects) to perform preliminary examinations with the CSAPPA scale and when suspicion of DCD exists to perform a series of standardised tests.

CHAPTER 7: LIMITATIONS

It is logical to assume that the experiments of the present research work may have been influenced by a number of limitations.

The higher prevalence rate of DCD (19%) observed in the first study compared to the 6-10% which is usually reported (American Psychiatric Association, 1994) may have been influenced by the sensitivity of the standardised test itself to accurately classify DCD cases among the Greek sample. Despite that the BOTMP-*sf* has been validated for use with Greek children (Kambas and Aggeloussis, 2006), these children were about two years younger than the ones involved in the present first experiment. It is also logical to assume that the current results might have been influenced by the lack of appropriate culture specific cut-offs for this specific population. It could be therefore that the BOTMP-*sf* may have overestimated the DCD prevalence rate for the present sample. The current findings might have also been influenced by the fact that the first study did not take into account the exclusive criteria that are mentioned in the DSM-IV (American Psychiatric Association, 1994). In particular, there is a recent tendency to measure IQ [i.e children with $IQ \leq 70$ should not be screened for DCD (Sugden, 2007)] however this method was not adopted herein. Greek children with an IQ equal or lower than 70, do not usually attend typical classes.

Another limitation of the first study is related to the use of the CSAPPA scale as a means for assessing the activities of daily living of children with DCD. The design of this scale does not cover all the difficulties that children with DCD might come across during their daily routines. Thus, the present results from the CSAPPA scale should be treated with caution. A similar point should be

considered for the PQ questionnaire. The PQ was not designed for use with DCD children even though it has been used in previous studies investigating activity patterns of children with the condition (Faught et al., 2005). It is rather a self administered questionnaire, and there is a great possibility that children may have responded in the questions with more enthusiasm, and thus overestimated their actual physical activity participation.

Considering the small sample of the suspected DCD⁺ cases in study 2, the present results should be treated with prudence. Although the BOTMP-*sf* has been used before to identify DCD cases, it has to be highlighted that this method yields “probable” or “suspect” cases. It is the actual difference in the prevalence rates of DCD between studies 1 and 2 that strengthens the above point. Even more, the BOTMP-*sf* is a standardised test that assesses the ability of the child to perform in tasks that measure motor proficiency per se, not the actual impairment. The inclusion criteria for DCD (American Psychiatric Association, 1994) should involve measurements with standardised tests and other aspects of the child’s development.

There is also other information regarding the typical or atypical development of the child that is missing from the second study. For example, parents were not asked whether their child was born prematurely or with low birth weight. These are factors that are known to influence motor performance (Holsti et al., 2002). The maturation status is another issue that should be considered when comparing childrens’ performances. However, due to time consuming and other reasons this parameter was not assessed.

Several limitations might have also influenced the results of the third study. First, it was the very nature of the exercise training programme which focused on the improvement of general abilities of children with and without DCD and which was not individually based. This might have influenced the results in terms of performance improvement. Children with DCD are a heterogeneous group with differing signs and symptoms [(i.e. academic, social, self-maintenance, motor proficiency) (Green et al., 2006, Skinner and Piek, 2001)] and it is logical to assume that the exercise intervention adopted in the present study could not have improved the functional performance of all DCD cases, because the problem of each case might have not been functional in the

first place. Furthermore, International Consensus meetings (Sugden, 2006) have identified that holistic, individualized and child-centered approaches (Hillier, 2007) should be applied in order for the child with DCD to improve. However, in school-based studies, such as the one herein, it is almost impossible to apply individualised interventions due to the fact that during school hours children are obliged to function in group activities.

Even though the fourth study used data from studies 1, 2 and 3, and these limitations are reported in the previous paragraphs, it is reasonable to assume that this study might have been presented with additional limitations. While the present results suggest that the CSAPPA scale can be used to identify children with DCD, it is best to assume that this method, because of its form (i.e self administered) might not be able to identify all DCD cases or may be subject to overestimation. Besides the fact that previous studies have used the CSAPPA scale and it's subscales as an additional tool for the identification of DCD (Cairney et al., 2005, Cairney et al., 2006, Cairney et al., 2007, Hay et al., 2004), more studies are needed in order to establish this method as a DCD identification instrument. Furthermore, because CSAPPA scale was not originally designed to identify DCD cases, rather than perceptions of adequacy of school-aged children, it is logical to address the fact that this scale does not take into account the diagnostic criteria internationally set for the diagnosis of DCD (American Psychiatric Association, 1994). Therefore, substitution of a standardised screening instrument for DCD with the CSAPPA scale is not recommended.

CHAPTER 8: CONCLUSION AND RECOMMENDATIONS FOR FUTURE RESEARCH

It is concluded that Greek children exhibit greater prevalence rates for DCD, CL_{OB}, L_{CF} compared to an overseas sample, while increased levels of physical activity may assist in reducing such prevalence rates in children.

At the same time Greek children with DCD tend to perform worse in selected physical fitness components compared to their normal peers and these results are supported by self reported questionnaires regarding physical activity engagement.

While exercise interventions for the prevention of skills and health related performance decline are overlooked in groups of children with DCD, the present results suggest that this approach may well serve as a means of ameliorating both skills and health related performance in Greek children.

Provided that all the three main studies of this research work have shown that children with DCD are presented with an increased risk for obesity and fitness deterioration, overall the results of the fourth study have shown that it is inactivity that places children with DCD at this risk. These results strengthen previously published data (Schott et al., 2007) which suggest that participation of children with DCD in general tasks that require motor dexterity is compromised. Results from the fourth study revealed that the CSAPPA scale, which is a tool for addressing such an issue, might serve as a useful means of initially identifying children at risk for DCD, prior to further proper assessment with standardised tests.

Future directions should aim at identifying children with DCD by taking into account both inclusive and exclusive diagnostic criteria set by the DSM-IV (1994). This will further assist the proper identification of children with DCD, since the heterogeneity of the signs and symptoms of this group of children implies that several assessments should be applied. For example, measurements such as IQ estimation, handwriting abilities, social participation, co-occurrence of DCD with other disorders (i.e ADHD) should be identified at an early stage in order for appropriate interventions to be practiced.

Appropriate interventions should aim at longer duration programmes in order for the skills and health related benefits to take place. Following proper identification of the impairment, therapeutic interventions should be targeted at rehabilitating the specific problem and enhancing relevant characteristics of skilled and fitness performance. This might be accomplished with the use of multidisciplinary aspects of the different treatments that are currently offered by professionals in the field.

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APPENDIX 1: Terminology of health and skills related fitness

Health related fitness

Cardiorespiratory endurance

The ability of the circulatory and respiratory systems to supply fuel during sustained physical activity and to eliminate fatigue products after supplying fuels.

Muscular endurance

The ability of the muscle groups to exert external force for many repetitions or successive exertions.

Muscular strength

The amount of external force that a muscle can exert.

Body composition

The relative amounts of muscle, fat, bone and other vital parts of the body.

Flexibility

The range of motion available at a joint.

Skills related fitness

Agility

The ability to rapidly change the position of the entire body in space with speed and accuracy.

Balance

The maintenance of the equilibrium while stationary or moving.

Coordination

The ability to use senses, such as sight and hearing, together with body parts in performing motor tasks smoothly and accurately.

Speed

The ability to perform a movement within a short period of time.

Power

The rate at which one can perform work

Reaction Time

The time elapsed between stimulation and the beginning of the reaction to it.

APPENDIX 2: Copy of Study 1 as published in The Journal of Adolescent Health

APPENDIX 3: Greek and English version of the Individual Consent Form used in Studies 1 and 2



ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ
ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΦΥΣΙΚΗΣ ΑΓΩΓΗΣ ΚΑΙ ΑΘΛΗΤΙΣΜΟΥ



Πανεπιστήμιο
Wolverhampton, Αγγλία

ΕΝΗΜΕΡΩΤΙΚΟ ΕΝΤΥΠΟ

ΕΡΕΥΝΗΤΡΙΑ: ΓΕΩΡΓΙΑ Δ. ΤΣΙΟΤΡΑ, Διδακτορική Φοιτήτρια Πανεπιστημίου Wolverhampton, Αγγλία

Τίτλος Ερευνητικού Έργου: "Το Σύνδρομο Μειωμένης Συντονιστικής Ικανότητας σε παιδιά σχολικής ηλικίας"

Αγαπητέ Γονέα/Κηδεμόνα, Αγαπητέ Μαθητή:

Κύριος σκοπός της μελέτης είναι να διαπιστωθεί το ποσοστό των παιδιών ηλικίας 10-12 ετών, που φοιτούν σε δημοτικά σχολεία των Τρικάλων, και που πάσχουν από το σύνδρομο της «Μειωμένης Συντονιστικής Ικανότητας». Δευτερεύων σκοπός της έρευνας είναι να διερευνηθούν οι παράγοντες που σχετίζονται με το επίπεδο της φυσικής δραστηριότητας στο ίδιο δείγμα παιδιών. Η χρησιμότητά της εστιάζεται στην ανάγκη για βελτίωση του μαθήματος της Φυσικής Αγωγής και των δραστηριοτήτων αναψυχής που έχουν άμεση σχέση με την υγεία και διεξάγονται στο σχολικό χώρο. Οι μετρήσεις στις οποίες θα υποβληθούν οι μαθητές αφορούν στην εκτέλεση σωματομετρικών τεστ, τεστ κινητικών ικανοτήτων και φυσικής κατάστασης, στην συμπλήρωση 2 ερωτηματολογίων σχετικών με την συμπεριφορά των μαθητών απέναντι στη φυσική δραστηριότητα και το επίπεδο της φυσικής δραστηριότητας, στην εκτέλεση ενός τεστ Αντοχής, καθώς και στην μέτρηση του λίπους. Όλες οι μετρήσεις είναι επιστημονικά ελεγμένες και εντελώς ακίνδυνες. Η συμμετοχή στην έρευνα απαιτεί περίπου τρεις ώρες από το χρόνο των μαθητών στο σχολείο και μπορούν να συμμετάσχουν σε αυτή μόνο μαθητές που συμμετέχουν στο μάθημα της Φυσικής Αγωγής. Οι μαθητές που δεν επιθυμούν να συμμετάσχουν μπορούν να συνεχίσουν τα μαθήματά τους κανονικά. Εκπαιδευμένο προσωπικό, συμπεριλαμβανομένου της κύριας ερευνήτριας θα διεξάγει όλες τις μετρήσεις. Η συμμετοχή του παιδιού σας είναι καθαρά εθελοντική και μπορεί ανά πάσα στιγμή να αποσυρθεί από τις μετρήσεις.

Η επεξεργασία των πληροφοριών που θα μας δώσουν οι μαθητές θα γίνει από την ομάδα η οποία διεξάγει τα τεστ και η ανάλυση των δεδομένων θα γίνει με τη βοήθεια στατιστικών προγραμμάτων σε ηλεκτρονικό υπολογιστή όπου η ανωνυμία των μαθητών θα διατηρηθεί αυστηρά. Όταν η έρευνα ολοκληρωθεί μια συνολική αναφορά στα ευρήματα της έρευνας θα είναι διαθέσιμη σε εσάς τους γονείς την οποία μπορείτε να παραλάβετε από την Γραμματεία του σχολείου. Επιπλέον, ο κύριος ερευνητής έχει σκοπό να δημοσιεύσει τα ευρήματα από αυτή την έρευνα σε επιστημονικό περιοδικό, όπου πουθενά δεν θα δίνονται συγκεκριμένες πληροφορίες σχετικά με τους συμμετέχοντες στην έρευνα. Εάν έχετε οποιαδήποτε ερώτηση σχετικά με τη μελέτη αυτή παρακαλώ να επικοινωνήσετε με την Διδακτορική Φοιτήτρια Τσιότρα Γεωργία στο τηλέφωνο 6932 642 649 ή στην ηλεκτρονική διεύθυνση gtsiotra@hotmail.com

Ευχαριστούμε για τη βοήθειά σας
ΤΣΙΟΤΡΑ Δ. ΓΕΩΡΓΙΑ

✂-----Παρακαλώ να επιστραφεί η φόρμα αυτή στην ερευνήτρια-----

ΕΓΚΡΙΣΗ ΑΠΟ ΤΟ ΓΟΝΕΑ/ΚΗΔΕΜΟΝΑ

Κωδικός μαθητή :

Σχολείο:

☐ **Δίνω την έγκρισή μου** να συμμετέχει ο γιος/κόρη μου στην έρευνα που διεξάγετε από την κ. Τσιότρα Γεωργία.

☐ **Δεν δίνω την έγκρισή μου** να συμμετέχει ο γιος/κόρη μου στην έρευνα που διεξάγετε από την κ. Τσιότρα Γεωργία.

Υπογραφή Γονέα/Κηδεμόνα: _____

Ημερομηνία: _____

Υπογραφή Μαθητή: _____

Ημερομηνία: _____

Παρακαλώ επιστρέψτε αυτή τη φόρμα στην ερευνήτρια όσο το δυνατόν πιο γρήγορα



Informed Consent

Project Investigator: GEORGIA D. TSOTRA, MPhil/Ph. D student

Title of study: "Developmental Coordination Disorder in School-aged Children".

Dear Parents/Guardians, Dear pupil:

The aim of this study is to investigate the parameters related to the level of physical fitness in school-aged children affected by Developmental Coordination Disorder. This is to mainly emphasize on the need for improvement of the Physical Education classes and the activities that are closely related to health and are being conducted within the school's playground. This project involves measurements that require from the pupils to perform at specific motor physical tasks, to fill in two questionnaires related to the attitude towards physical activity and the level of physical activity. Children will also be required to complete a battery of tests for the evaluation of motor skills and a battery of tests for the evaluation of their physical fitness and body composition. All tests are scientifically checked and no danger is being involved. Participation in this project requires approximately 120 minutes of the pupils' school time. Only pupils who are officially engaged in Physical education classes can take part in this project. Children who are not interested in participating can continue their classes. Trained University personnel will carry out all measurements. Your child's participation is voluntary and he/she may withdraw from the study at any time.

Data analyses, drawn from the study, will be performed from the University personnel with the aid of statistical packages on a PC, where anonymity will be strictly preserved. When the study is complete a summary report will be available to you from the School's registry. Furthermore, the researcher intends to publish the findings from this study in scientific journals without exposing personal information regarding the participants.

Should you have any questions related to the study, please don't hesitate to contact Mrs. Georgia D. Tsiotra, (Ph. D student) in the following telephone number 6932 642 649 or in the e-mail address: gtsiotra@hotmail.com

Thank you for your help

Georgia D. Tsiotra

✂----- Please return this form to the researcher -----

Parental Approval

Child's code :

School:

☐ **I give permission** for my child to participate in the study being conducted by
Mrs. Georgia D. Tsiotra

☐ **I do not give permission** for my child to participate in the study being conducted by
Mrs. Georgia D. Tsiotra

Signature of Parent/Guardian: _____ Date: _____

Signature of Pupil: _____ Date: _____

PLEASE RETURN THIS FORM TO THE RESEARCHER AS SOON AS POSSIBLE

APPENDIX 4: Greek and English version of the BOTMP-*sf*

APPENDIX 5: Greek and English version of the CSAPPA scale

APPENDIX 6: Greek and English version of the PQ

APPENDIX 7: Copy of Study 2 as published in Pediatric Exercise Science

APPENDIX 8: Greek and English version of the Individual Consent Form used in Study 3



ΠΑΝΕΠΙΣΤΗΜΙΟ ΘΕΣΣΑΛΙΑΣ
ΤΜΗΜΑ ΕΠΙΣΤΗΜΗΣ ΦΥΣΙΚΗΣ ΑΓΩΓΗΣ ΚΑΙ ΑΘΛΗΤΙΣΜΟΥ



Πανεπιστήμιο
Wolverhampton, Αγγλία

ΕΝΗΜΕΡΩΤΙΚΟ ΕΝΤΥΠΟ

ΕΡΕΥΝΗΤΡΙΑ: ΓΕΩΡΓΙΑ Δ. ΤΣΙΟΤΡΑ, Διδακτορική Φοιτήτρια Πανεπιστημίου Wolverhampton, Αγγλία

Τίτλος Ερευνητικού Έργου:

"Το Σύνδρομο Αναπτυξιακής Διαταραχής Συντονισμού σε παιδιά σχολικής ηλικίας"

Αγαπητέ Γονέα/Κηδεμόνα, Αγαπητέ/ή Μαθητή/τρια:

Η μελέτη αυτή γίνεται σε συνεργασία με την Περιφέρεια Δυτικής Ελλάδας, το Τμήμα Επιστήμης Φυσικής Αγωγής και Αθλητισμού του Πανεπιστημίου Θεσσαλίας και το Πανεπιστήμιο Wolverhampton της Μεγάλης Βρετανίας. Κύριος σκοπός της μελέτης είναι να διαπιστωθεί το ποσοστό των παιδιών ηλικίας 10-12 ετών, που φοιτούν σε δημοτικά σχολεία, και που πάσχουν από το Σύνδρομο Αναπτυξιακής Διαταραχής Συντονισμού (ΣΑΔΣ). Η χρησιμότητά της παρούσας μελέτης εστιάζεται στην ανάγκη για περαιτέρω γνώση σχετικά με το ΣΑΔΣ και τις επιπτώσεις του στην υγεία και τα επίπεδα της φυσικής δραστηριότητας και φυσικής κατάστασης παιδιών στην ηλικία των 10-12 ετών. Οι μετρήσεις στις οποίες θα υποβληθούν οι μαθητές αφορούν στην εκτέλεση σωματομετρικών τεστ, τεστ κινητικών ικανοτήτων και φυσικής κατάστασης, στην συμπλήρωση 2 ερωτηματολογίων σχετικών με την συμπεριφορά των μαθητών απέναντι στη φυσική δραστηριότητα και το επίπεδο της φυσικής δραστηριότητας, καθώς και στην μέτρηση του λίπους. Επιπλέον, για 2 μήνες και κατά την ώρα της φυσικής αγωγής τα παιδιά που θα αξιολογηθούν με το ΣΑΔΣ θα συμμετέχουν σε ένα ειδικό παρεμβατικό πρόγραμμα φυσικής κατάστασης για να διερευνηθεί κατά πόσο η φυσική δραστηριότητα και η βελτίωση των επιπέδων της φυσικής κατάστασης μπορούν να βελτιώσουν το ΣΑΔΣ. Οι παραπάνω μετρήσεις για το ΣΑΔΣ θα γίνουν 2 φορές, στην αρχή και στο τέλος του παρεμβατικού προγράμματος.

Όλες οι μετρήσεις είναι επιστημονικά ελεγμένες και εντελώς ακίνδυνες. Στην έρευνα μπορούν να συμμετέχουν μόνο μαθητές που συμμετέχουν στο μάθημα της Φυσικής Αγωγής. Οι μαθητές που δεν επιθυμούν να συμμετάσχουν μπορούν να συνεχίσουν τα μαθήματά τους κανονικά. Ειδικά εκπαιδευμένο προσωπικό θα διεξάγει όλες τις μετρήσεις. Η συμμετοχή του παιδιού σας είναι καθαρά εθελοντική και μπορεί ανά πάσα στιγμή να αποσυρθεί από τις μετρήσεις.

Η επεξεργασία των πληροφοριών που θα μας δώσουν οι μαθητές θα γίνει από την ομάδα η οποία διεξάγει τα τεστ και η ανάλυση των δεδομένων θα γίνει με τη βοήθεια στατιστικών προγραμμάτων σε ηλεκτρονικό υπολογιστή όπου η ανωνυμία των

μαθητών θα διατηρηθεί αυστηρά. Όταν η έρευνα ολοκληρωθεί μια συνολική αναφορά στα ευρήματα της έρευνας θα είναι διαθέσιμη σε εσάς τους γονείς την οποία μπορείτε να παραλάβετε από την Γραμματεία του σχολείου. Επιπλέον, οι ερευνητές έχουν σκοπό να δημοσιεύσουν τα ευρήματα από αυτή την έρευνα σε επιστημονικό περιοδικό, όπου πουθενά δεν θα δίνονται συγκεκριμένες πληροφορίες σχετικά με τους συμμετέχοντες στην έρευνα.

Εάν έχετε οποιαδήποτε ερώτηση σχετικά με τη μελέτη αυτή μπορείτε να επικοινωνήσετε μαζί μας στο τηλέφωνο 6932 642 649 ή στην ηλεκτρονική διεύθυνση gtsiotra@wlv.ac.uk

Ευχαριστούμε για τη βοήθειά σας.

✂-----Παρακαλώ να επιστραφεί η φόρμα αυτή στον Καθηγητή Φυσικής Αγωγής -----

ΕΓΚΡΙΣΗ ΑΠΟ ΤΟ ΓΟΝΕΑ/ΚΗΔΕΜΟΝΑ

Κωδικός μαθητή :

Σχολείο:

☐ Δίνω την έγκρισή μου να συμμετέχει ο γιος/κόρη μου στην έρευνα που διεξάγετε από την κ. Τσιότρα Γεωργία.

☐ Δεν δίνω την έγκρισή μου να συμμετέχει ο γιος/κόρη μου στην έρευνα που διεξάγετε από την κ. Τσιότρα Γεωργία.

Υπογραφή Γονέα/Κηδεμόνα: _____ Ημερομηνία: _____

Υπογραφή Μαθητή: _____ Ημερομηνία: _____

Παρακαλώ επιστρέψτε αυτή τη φόρμα στην ερευνήτρια όσο το δυνατόν πιο γρήγορα



Informed Consent

Project Investigator: GEORGIA D. TSIOTRA, MPhil/Ph. D student

Title of study: "Developmental Coordination Disorder in School-aged Children".

Dear Parents/Guardians, Dear pupil:

The aim of this study is to investigate the parameters related to the level of physical fitness in school-aged children affected by Developmental Coordination Disorder. This is to mainly emphasize on the need for improvement of the Physical Education classes and the activities that are closely related to health and are being conducted within the school's playground. This project involves measurements that require from the pupils to perform at specific motor physical tasks, to fill in two questionnaires related to the attitude towards physical activity and the level of physical activity. Children will also be required to complete a battery of tests for the evaluation of motor skills and a battery of tests for the evaluation of their physical fitness, as well as to participate in a two months exercise training programme, of two to three times per week, for the development and improvement of their motor skills.

All tests are scientifically checked and no danger is being involved. Participation in this project requires approximately 120 minutes of the pupils' school time. Only pupils who are officially engaged in Physical education classes can take part in this project. Children who are not interested in participating can continue their classes. Trained University personnel will carry out all measurements. Your child's participation is voluntary and he/she may withdraw from the study at any time.

Data analyses, drawn from the study, will be performed from the University personnel with the aid of statistical packages on a PC, where anonymity will be strictly preserved. When the study is complete a summary report will be available to you from the School's registry. Furthermore, the researcher intends to publish the findings from this study in scientific journals without exposing personal information regarding the participants.

Should you have any questions related to the study, please don't hesitate to contact Mrs. Georgia D. Tsiotra, in the following telephone numbers 6932 642 649 or in the e-mail address: gtsiotra@hotmail.com

Thank you for your help

Georgia D. Tsiotra

✂----- Please return this form to the child's class teacher -----

Parental Approval

Child's code :

School:

☐ I give permission for my child to participate in the study being conducted by
Mrs. Georgia D. Tsiotra

☐ I do not give permission for my child to participate in the study being conducted by
Mrs. Georgia D. Tsiotra

Signature of Parent/Guardian: _____ Date: _____

Signature of Pupil: _____ Date: _____

PLEASE RETURN THIS FORM TO THE RESEARCHER AS SOON AS POSSIBLE